Respectfully Presented
To His Grace The Duke of Somerset

&c. &c. &c.

By
The Directors of The Thames
Water Joint Stock
Company

October 1836.—

Reduced Plan
of Lands drained into the
RESERVOIRS,
and into the
AQUEDUCT
near GREENOCK,
with Sections of the
MILL SEATS,
-1827-
F G H, the Aqueduct between 6 & 7 miles long.
N O X, East line of Mill Leads.
O Y, West line of Mill Leads.
Great Reservoir
Killochend
Shaws
Shaws Hill
Road to Greenock
Darndaff Hill
Whinhill
Aqueduct
Waster
Regulating Reservoir
Everton
GREENOCK
FRITH OF CLYDE
No. 4 Aux. Res.
No. 5 Aux. Res.
No. 6 Aux. Res.
512 ½ Feet
368
REFERENCE.
Impl. Acres.
Ground, the Waters of which are drained into the Great Reservoir 3600.76
Ground drained by the Compensation Reservoir 344.08
Ground drained by the stream for regulating the Weather sluices 81.65
Ground drained by the Aqueduct 955.98
Total 4982.47

A
BRIEF ACCOUNT
OF THE
SHAWS WATER SCHEME,
AND PRESENT STATE OF
The Works:

WITH COPIES OF THE FEU CHARTER, AND REGULATIONS TO BE ENTERED INTO BETWEEN THE COMPANY AND FEUARS OF MILL SITES; TABLES OF CONTENTS OF RESERVOIRS; AND DRAWINGS AND DESCRIPTIONS OF THE VARIOUS HYDRAULIC CONTRIVANCES EMPLOYED IN COLLECTING, ECONOMIZING, AND BRINGING HOME THE WATER TO THE MILLS: WITH A LETTER FROM MR. THOM, TO SIR MICHAEL SHAW STEWART, ON THE PRINCIPLES OF FILTRATION, AS APPLICABLE FOR THE SUPPLY OF POPULOUS TOWNS AND CITIES WITH PURE WATER.

GREENOCK:
PRINTED AT THE COLUMBIAN PRESS.

MDCCCXXIX.

ERRATA.

Page 13, **Seventh line from the bottom, for *where* read *when*.**

19, **Third line from the top, substitute a *comma* for a *semicolon*, after "aqueduct."**

Fourth line from the top, substitute a *semicolon* for a *comma*, after "mills."

62, **First line, delete the words, "for the purpose of ascertaining and fixing."**

BRIEF ACCOUNT

OF THE

SHAWS WATER SCHEME.

It is but too well known that Greenock has heretofore been so ill supplied with water, that, during every dry season, it had to be carted from a distance for the ordinary supply of the inhabitants.

To remedy this, several surveys were made, at different times, by different Engineers, but without effect till 1824, when, at the desire of Sir Michael Shaw Stewart, Mr Thom inspected all the grounds in the vicinity of Greenock, and found that it was practicable, not only to give the *contemplated* supply of Water to the inhabitants, *but such a supply as would also impel Machinery, to an extent at least equal to all the Machinery then impelled by Steam Power in and about Glasgow.*—See Mr. Thom's Report, 22d June, 1824.

In consequence of this Report, and under the immediate auspices of the late Sir Michael Shaw Stewart, and of his son and successor, the present Sir Michael, a Joint Stock Company, with a capital of thirty one thousand pounds, was incorporated by Act of Parliament, for carrying the plan into effect.

For the information of Proprietors at a distance, and others interested, we subjoin a Plan of the whole, with a brief description of the present state of the Works, and their capability of farther extension; together with copies of the Feu Charter and Regulations to be entered into between the Company and the Feuars of Mill Sites; also, tables of the contents of the several Reservoirs, at various depths, from low to high water mark; with drawings and descriptions of the various self-acting sluices employed in collecting, economizing, and bringing home the water to the Mills.

The compensation reservoir, the auxiliary reservoir No. 3, the main aqueduct, (something more than six miles in length) and the eastern line of mill leads, were finished early in April 1827, and on the 16th day of that month the water, from the great reservoir, was brought along the aqueduct, and down this eastern line to the Baker's Mill; which has ever since been supplied at the rate of twelve hundred cubic feet per minute for twelve hours in the day, agreeably to the regulations. Other three Mill Sites have also been feued on this line, and the necessary erections are in a considerable state of forwardness.

The embankment of the great reservoir, which is 60 feet high from the bottom of the rivulet, is now very nearly, and in a few months will be entirely finished.

This reservoir contains two hundred and eighty four millions, six hundred and seventy eight thousand, five

hundred and fifty (284,678,550) cubic feet of water; and covers two hundred and ninety four and three fourths imperial acres of land.

The compensation reservoir contains fourteen millions, four hundred and sixty five thousand, eight hundred and ninety eight (14,465,898) cubic feet of water; and covers about forty imperial acres. Its embankment is 23 feet high from the bottom of the rivulet.

The auxiliary reservoir, No. 3, contains four millions, six hundred and fifty two thousand, seven hundred and seventy five (4,652,775) cubic feet of water; and covers about ten imperial acres.

The other auxiliary reservoirs, Nos. 1, 2, 4, 5, and 6, are now about to be formed, and will contain something more than six millions cubic feet of water.

Thus, the reservoirs already formed, contain three hundred and three millions, seven hundred and ninety seven thousand, two hundred and twenty three (303,797,223) cubic feet; and when the other five auxiliary reservoirs are finished, the whole will contain above three hundred and ten millions (310,000,000) cubic feet of water.*

The whole annual supply, originally *estimated* by Mr Thom to be brought to Greenock, was six hun-

* The regulating reservoir at the Whin-hill, contains cubic feet of water, and is to be enlarged to something more than double its present capacity; but as its chief use is *as a regulator*, its contents have not been here taken into the calculation.

dred millions (600,000,000) cubic feet. The Company have stipulated to supply the east line of Mills with twelve hundred (1200) cubic feet per minute, for three hundred and ten days, (of twelve hours each) in the year; and it is intended to give an equal supply to the west line. This will amount to five hundred and thirty five millions, six hundred and eighty thousand (535,680,000) cubic feet annually. Taking the population of Greenock at 25,000, and allowing for each individual two cubic feet a day, this will require eighteen millions, two hundred and fifty thousand cubic feet annually; which leaves, of the original six hundred millions, forty five millions, seventy thousand (45,070,000) cubic feet annually, for the public works and other purposes.

But the experience of the two last years has proved that the available drainage into the various reservoirs now formed, is above seven hundred millions of cubic feet annually; and it will be observed that the reservoirs are capable of containing a full supply for the whole consumpt for more than six months; so that not only the surplus waters of one wet season may be retained for supplying the dry season of the *same* year, but the surplus of *several* wet years stored up to supply a drought of several years duration, should such ever occur.—*And as Mr Thom has shewn, that additional drainage, to great extent, might still be made available for these works, any doubt of a full supply of water, at all times and in all seasons, to an*

extent much beyond what has been stipulated for by the Company, is altogether out of the question.

The water for the supply of the *inhabitants, sugar works,* and others requiring *pure* water, is collected into reservoirs, *set apart for that purpose,* and as little as may be of moss water admitted into them. A separate aqueduct has also been made to carry this water to the filters, just above the town, where a basin has also been made, large enough to contain something more than a day's supply of the filtered water. This aqueduct, which is fully fifteen inches square, is perfectly water tight; being formed with stone, nicely joined and cemented; and costs something less than one third the price of a cast iron pipe of equal capacity. Wherever the pressure is not great, such a conduit is preferable to an iron pipe; as the water by passing over stone is rather improved than injured, which is not the case with iron. In this aqueduct, (which is deep enough in the earth to avoid the frost of winter and heat of summer,) cess pools are formed for the deposit of sediment; it being desirable that the water should be as pure as the nature of things will permit before it enters the filters.* The medium

* Because the less sediment there is in the water when it *enters* the filter, the more water will the filter produce: and with regard to moss water, or water in which such matter is *dissolved,* the substance used to remove such matter, will, in time, become *saturated,* and must then be exchanged; and as this is expensive, there should no moss water be allowed to enter the filters that can be prevented.

through which the water percolates in these filters has been made such, as not only to detain any *sediment that may remain,* but also the *colouring matter* of moss water and other similar impurities, should there chance to be any such.

Three filters are now formed: each is fifty feet long, twelve wide, and eight deep. The water is made to percolate through them, *either upwards or downwards, at pleasure.* When it percolates downwards, and the supply of filtered water becomes sensibly less—which, after some time, must happen to every filter, by the lodgement of sediment—then, by shutting one sluice, and opening another, the water is made to pass upwards with considerable force, and, carrying the sediment along with it, falls into a waste drain made for that purpose. When the lodged sediment is thus removed, and the water begins to run clear, the direction of the sluices is again changed, and the filter operates as before.

If the water usually percolates upwards, then, as before, when the quantity of filtered water falls short, one sluice is shut and another opened, and the water, passing downwards with considerable force, carries the sediment along with it into the waste drain. In either case, the sediment is removed, and the filter again at work in less than an hour. This much sought for desideratum in filters has, therefore, at last been found; and Greenock is now supplied with abundance of pure water, at the very low rate of 6d. the pound of rental,

being only half the price paid in Edinburgh and Glasgow.

The distinguishing characteristics of *this scheme* are the following :—Instead of erecting works on natural waterfalls, on the banks of rivers, in remote and almost inaccessible places, where immense capital must, in the first instance, be expended in forming roads and houses for the work people, as well as a heavy and perpetual charge for carriage to and from the seat of trade,—the water is carried, by an aqueduct, from the river and reservoirs, to a populous sea-port town, with a redundant unemployed population, where roads, harbours, piers, and every thing requisite for the most extensive trade and manufacture, are already formed. Besides, by thus forming artificial waterfalls on advantageous grounds, every inch of fall, from the river or reservoir to the sea, is rendered available; whereas, by the former mode, only a very small part of the fall could, in general, be employed. In the present case a fall of 512 feet has been made available, of which not more than 20 was formerly occupied, or thought capable of being usefully employed. But, besides the immense advantage thus gained by increasing the fall, a still greater advantage is obtained from the greatly increased, and perfectly uniform, supply of water; by the adaptation of the various reservoirs, aqueducts, basins, and self-acting sluices—as will be seen by the description of the parts which they respectively perform.

It has already been stated that the reservoirs have

weather sluices,* of equal apertures, are placed; the whole six being calculated to pass exactly the quantity of water required for the Mills, and other purposes at Greenock. A similar weather sluice, (but to act also as a waster when necessary,) is placed upon the lower end of the tunnel of the auxiliary reservoir No. 3, and a common hand sluice at its upper end; and similar sluices will be put upon the other five auxiliary reservoirs when completed.

On the aqueduct, wherever rivulets are intercepted by it, self acting wasters are placed, to pass the surplus water of *extraordinary floods* into the former beds of these rivulets.

On the upper end of the tunnel (K I near K) between the Whinhill reservoir (K J) and the basin (I L) just below, a common upright lifting sluice is placed; and, on its lower end, (near I) a self acting sluice;† which last keeps the water in this basin (I L) uniformly at a given height—and acts also as a waster when the reservoir gets too full. In the partition which separates this basin (I L) from the mill lead, (M) an aperture (L) is made which, with the water in the basin at the assigned height, passes exactly the stipulated quantity into this lead. On this aperture (L) a self acting valve is fitted, which opens whenever the

* The construction of these weather sluices is similar to those of fig. 8 in the Appendix.

† See fig. 4 in the Appendix; only this sluice turns on pivots near the centre, as in fig. 5 there.

water from the lead (M) is applied to the water wheel of the upper mill (near M), and shuts again whenever that mill is stopped. A waster sluice is also placed upon the level part of the lead, between each two mills, which keeps the water there uniformly at a given height. In this way the supply to the mills is kept quite regular and uniform; whilst it is out of the power of any one mill either to keep water from, or set back water upon, any other mill.

This much being premised, let us see how these various reservoirs, aqueducts, basins, and sluices contribute in economizing the water, and bringing home a regular supply to the mills.

Suppose the weather to be very dry, the auxiliary reservoirs all empty, the common upright lifting sluices every where open, and the whole supply required from the great reservoir. In this state of things, the six weather sluices on the basin, (E) below the compensation reservoir, being all open, will pass the necessary supply into the aqueduct; the self acting sluice (I) on the tunnel between the Whinhill reservoir and basin (I L) just below, will pass it into this basin; and the self acting valve (L) will pass it into the mill lead (M) and thence to the mills. Whilst, therefore, such drought continues, it is only necessary to throw open the common upright lifting sluice (C) on the tunnel of the compensation reservoir in the morning, and shut it at night; and the several self acting sluices will bring home exactly the stipulated quantity of water to

of such magnitude and duration as to shut the whole of the weather sluices in succession. This, however, will not often happen :—in most cases the rains will abate by the time that one, two, or three of them have shut ; but at whatever stage it may cease or abate, those sluices that have shut will always open again in succession, as the drainage into the aqueduct lessens ; *and thus, at all times, and in all kinds of weather, pass exactly the stipulated quantity of water to the mills, without waste and without water man.*

It has been stated that the six weather sluices at the basin (C) will exactly pass the quantity of water required by the Mills. It may therefore be supposed, that, when all the auxiliary reservoirs are finished, and all the twelve weather sluices open, they will pass too much water to the mills. But it will be observed, that the sluice which shuts last is always the one that opens first, and so in succession: and as, by construction, the last of these sluices can never shut till at or near the end of the greatest flood, they can only be shut for a very short period, and of course have collected very little water ; and, therefore, what any one of these auxiliary reservoirs may have thus collected, will always be run off by the time that the third or fourth, after it in rotation, has opened : so that from the construction of these auxiliary reservoirs, there can never be more than six of the weather sluices passing water to the mills at any one time.

It is also to be observed, that the very *use and de-*

sign of the reservoir at the Whinhill, *is that of a regulator*, for preventing any small irregularity in the conveyance of the water along the aqueduct; from affecting the regular supply given out by it to the mills, as well as to retain part of the water of extraordinary floods, which would otherwise have to be wasted from the aqueduct. Hence it is obvious, how important a part these auxiliary reservoirs and self-acting sluices perform in this system of water power.


Rivulet
Rivulet
WATER
Great Reservoir
Road to Greenock

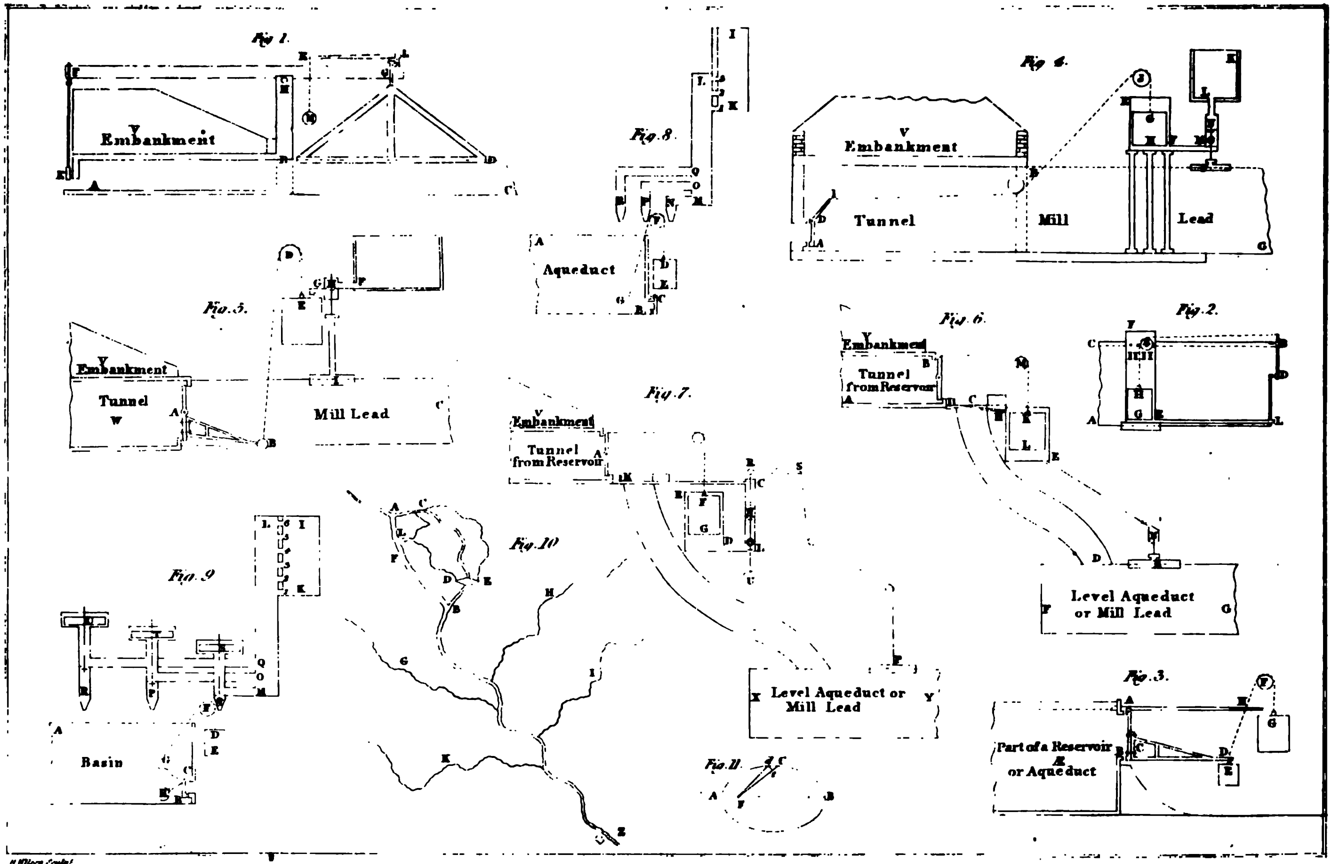
Fig. 1.
Embankment
Fig. 8.
Aqueduct
Fig. 4.
Embankment
Tunnel
Mill
Lead
Fig. 5.
Embankment
Tunnel
Mill Lead
Fig. 7.
Embankment
Tunnel from Reservoir
Fig. 6.
Embankment
Tunnel from Reservoir
Fig. 2.
Level Aqueduct or Mill Lead
Fig. 9.
Basin
Fig. 10
Level Aqueduct or Mill Lead
Fig. 11
Fig. 3.
Part of a Reservoir or Aqueduct

APPENDIX.

A Short Account of the various Self-Acting Sluices, and other Hydraulic Contrivances, for Collecting and Economizing a Supply of Water; and for Regulating its Conveyance between Rivers, Reservoirs, Mills, &c.: as contrived or invented by Robt. Thom, Civil Engineer, Rothsay.

THE LEVER SLUICE, FIGURE 1.

THIS apparatus, when placed on a reservoir that supplies any canal, mill, or other work with water, (where the aqueduct between the reservoir and such work is on a level,) will always open of its own accord, and let down the quantity of water wanted by such work and no more; so that it not only supersedes a water man, but also saves a great deal of water.

A B, a tunnel through which the water passes from the reservoir to

B C, the aqueduct that carries the water to the mills.

B D, a float that rises and falls with the water in the aqueduct.

A, an aperture in the mouth of the tunnel.

E, the self-acting sluice that opens and shuts that aperture.

F G, a lever which turns upon fulcrum H, and is connected at one end with sluice E, and at the other end with float B D.

The sluice E is here represented open, and the mills going;

but when the mills are stopped, the water rises in the aqueduct, and with it float B D, which raises the end G and lowers the end F, of the lever F G, and shuts sluice E. When the water is again let upon the wheel at the mills, the surface of the aqueduct falls and with it the float, which opens sluice E as before.

Upon the lever F G, there is another small lever K L, which turns upon fulcrum L, and has a weight M suspended to the other end K. In the ordinary working of the apparatus this lever is quite stationary, and produces no effect whatever ; but during floods the water in the aqueduct is raised by streams that flow into it between the reservoir and the mills ; and when this happens, and the mills not at work, the water, rising in the aqueduct, presses up the float upon one end of the lever when the other end cannot descend ; and would thereby strain or break the apparatus, but for this contrivance by which the extra pressure merely pushes up the small lever K L. Of course, the weight M is so adjusted that the lever K L will not move till the sluice is shut, but will rise upon the least extra pressure afterwards.

The dimensions of the float are nineteen feet square, by seven inches deep ; the lever is twenty-seven feet long, being twice the length between the fulcrum and the sluice, that it is between the fulcrum and the float. The sluice is three feet three inches long, and fifteen inches deep.

To determine the proper dimensions of the float, and relative lengths of the ends of the lever, it was necessary to ascertain how far the sluice required to be raised to pass the quantity of water wanted, and also how far the water in the aqueduct *might* be raised above the level *necessary* for supplying the works : the first was found to be seven inches, the last only four inches. The end of the lever connected with the float was made, therefore, only half the length of the end connected with the sluice ; and the float was made of such dimensions, that, when sunk half an inch in water, the weight of water thereby displaced was equal to twice the

weight required to shut the sluice.* When therefore the water in the aqueduct rises upon the float half an inch, (besides what it sinks by its own weight,) the sluice begins to move; and by the time the water rises other three inches and a half, the sluice is of course seven inches down, or shut. This apparatus was erected at Rothsay in 1816.

THE WASTER SLUICE, FIGURE 2.

This sluice, when placed upon the embankment of any river, canal, reservoir, or collection of water, prevents the water within the embankment from rising above the height we choose to assign to it; for whenever it rises to that height, the sluice opens and passes the extra water; and whenever that extra water is passed, it shuts again, so that, while it saves the banks at all times from damage by overflow, it never wastes any water we wish to retain.

A C B L, part of a canal, river, stream, or collection of water.

B C, high water mark, or the greatest height to which the water is to be allowed to rise.

B D, a sluice, or folding dam, which turns on pivots at D.

E F, a hollow cylinder, having a small aperture in its bottom, to which is joined

E L, a small pipe, *always open.*

I I I I, small holes in cylinder E F, on the line of high water mark.

* Twice the weight, because here the lever is two to one against the float.

To ascertain the power required to open or shut the sluice, (which is easily done by a lever and weights previously applied to it,) it must be tried when the water in the reservoir is at the *highest;* which, in this case, is seven feet above the bottom of the sluice. To ascertain how far the sluice must be raised to pass the necessary supply, it must be tried when the water in the reservoir is at the *lowest;* and in this instance was done when it stood three feet above the bottom of the sluice. The quantity of water required is equal to about the power of fifty horses, the fall at the wheel being twenty feet. The aqueduct is about seven hundred yards long, twelve feet wide, three deep; and its bottom about twelve inches lower than the bottom of the sluice.

G H, another cylinder, water proof, that moves up and down freely within cylinder E F; and the weight of which keeps the sluice B D shut by its connection with

B K H, a chain fixed to cylinder G H at H; thence passing over pulley K, has its other end fixed to sluice B D at B.

When the water in the canal, river, or pond, rises to the line B C, it passes into cylinder E F, at the small holes I I I I; and this lessens the weight of cylinder G H so much that the pressure of the water in front of sluice B D throws it open. When the water subsides, so as not to enter these holes, the cylinder is emptied by the tube E L; and then the weight of cylinder G H shuts the sluice as before. The dimensions and weight of this cylinder must, of course, correspond with the weight of the column of water pressing upon sluice B D. An apparatus of this kind was first erected at Rothsay in 1817. The dimensions of one of these are:—Cylinder G H two feet diameter, and two feet deep; its weight 500 lbs.* Cylinder E F, five feet ten inches deep, two feet one inch diameter inside. Sluice B D, four feet long and two feet deep.

This sluice is here represented with the pivots (on which it turns) at its under edge; but they may be placed either at the upper or under edge, as circumstances require. The upper

* This weight is considerably more than necessary, when the sluice is placed with the pivots at its under, and the chain at its upper edge; but it was calculated to be powerful enough when the sluice was turned with the pivots at its upper, and the chain at its under edge, to which position it has since been changed.

Although the cylinder G H requires to be heavier to shut the sluice when its pivots are at the top, yet to pass the same quantity of water, it does not require to move half so far as when they are at the bottom, and therefore cylinder E F may be made much shorter; so that the cost in either case is nearly the same, or rather in favour of the pivots being at the top. In most cases this last position is preferable: there are instances, however, in which the other is more advisable; such as in a river where wood, ice, or other bulky substances, may be expected to float occasionally on the surface; but such cases require a particular construction, adapted to the circumstances.

edge, is also here represented on a level with high-water-mark ; but, if necessary, it may be placed any where between that and the bottom of the pond, or aqueduct ; or it may be placed right below, as on an aqueduct bridge, or similar situation. The cylinders may also be placed on the *outside* of the dam or embankment, by having a pipe to communicate between them and the water within ; but in whatever situation the sluice or cylinders may be placed, the pipe that communicates between the cylinders and the water within the embankment must always have its opening exactly at the level of high water mark, or at the greatest height to which the water is to be permitted to rise.

On this principle a self-acting dam may be raised in any river or stream, up to high-water-mark, by which means a considerable reservoir will be obtained ; whilst, during spates, the dam will fold down, and no new ground be flooded.

In lawns or pleasure grounds, through which streams or rivulets flow, these sluices might be applied to advantage ; for by placing one on the bank of each pond, the water within would always be kept at the same height, whether the weather were wet or dry ; and hence flowers or shrubs might be planted close to the water's edge, or in it, (as best suits their respective habits,) and their position with regard to water would always be the same.*

* If necessary, this sluice may be made to open *inwards, against the water ;* and shut by the pressure of the water *against it :* but in this case the sluice must be placed *within* the framing or pond, and cylinder G H be a light vessel, open at the top, with a hole in its bottom, like can G, figure 3. Then the water, falling into the vessel, would, by its weight, open the sluice B D : and when the surface of the water fell, so as no longer to flow into the vessel, it would be emptied by the aperture in its bottom ; and then the weight, or pressure, of the water upon sluice B D, would shut it. But, in this case, care must be taken to make the pipe E L large enough to carry off all the water that *can* enter at the holes I I I I; for, if allowed to rise *round* the vessel H G, it would lighten or float it ; and then sluice B D would shut when it ought to be open.

it sends down the whole supply from the reservoir; when these streams furnish a part, it sends down the remaining part, whatever it may be; and when these streams furnish the whole supply, it shuts the reservoir entirely: so that the supply of water to the mills is always the same, whether the weather be wet or dry.

To accomplish this, the whole number of sluices (B C) placed on the aqueduct A B, are calculated so as just to pass the whole quantity of water wanted at the mills; and as more or less water is produced by these streams, a greater or lesser number of these sluices will open or shut; so as to keep the quantity at the mills uniformly the same. The number of these sluices will be more or less as the case may require; in this we suppose three, as being sufficient to illustrate the principle.

Let us suppose, then, the weather very dry; the streams between the reservoir and the mills quite dried up; and the sluices B C all open: rain comes, and these streams begin to flow: but the same rains that swell these streams, swell also the rivulet I K; and by the time the first produce a quantity equal to what one sluice (B C) can pass, the last will have risen so as to flow out at aperture 1, thence down pipe L M N into can D E; which shuts sluice B C. When these streams increase, so as to produce as much water as two of the sluices (B C) can pass, then the rivulet I K will have swollen so as to flow out at aperture 2, and thence through P into a second can; which shuts a second sluice: when they increase so as to produce a quantity equal to what three of the sluices (B C) can pass, then the water in the rivulet I K, will have risen so as to flow out at aperture 3, and thence through R into a third can; which shuts a third sluice.

Again: suppose the weather to become fair, and the streams begin to decrease; by the time they fall short a quantity equal to what one sluice (B C) can pass, the water in the rivulet I K will have fallen so as not to flow out at aperture 3, and, of course, one can will be empty, and one sluice open: by the time the

fall short a quantity equal to what two sluices can pass, the water in the rivulet I K will have fallen so as not to flow out at aperture 2, and a second can will have become empty, and a second sluice open: when they shall have fallen short a quantity equal to what three sluices can pass, the water in the rivulet I K will have fallen so as not flow out at aperture 1, and a third can will have become empty, and a third sluice open, &c. &c.

In this way the water may be regulated at pleasure; and if a small reservoir were made near the works, to retain the water that flows during the night, (or when the Mills are not at work), not a drop would be lost.* The purpose, however, for which this apparatus was invented was different. Having occasion to cut an aqueduct round the bases of some hills, to collect water and convey it to a reservoir at a considerable distance, I found that to make the aqueduct large enough, to convey all the water *as it fell during floods*, would be very expensive; it therefore occurred to me, that if a part of the water could be detained during floods, and brought away gradually afterwards, a much smaller, and of course much less expensive, aqueduct would answer the purpose. I therefore made a small reservoir at a convenient place; and contrived these sluices, to shut during very heavy rains, and open again as they became lighter, which answered the purpose completely, and was the origin of all these weather sluices.

THE DOUBLE WEATHER SLUICES, FIGURE 9.

This apparatus is so far similar to the last described; but it has a double operation, the sluices first opening, one after another, as the streams increase, until they reach a given height;

* The apparatus figure 6, will accomplish the same thing without this small reservoir, but in most cases (particularly where the elevation of the reservoir above, and its distance from, the works is great,) the expense would be much greater than in this.

F G, a pipe which communicates between that cistern and cylinder E.

H, a valve that opens or shuts that communication.

I, a float that rises and falls with the water in the aqueduct.

The sluice A is here represented shut, and the water in the aqueduct at rest. But suppose a part of the water to be drawn from the aqueduct, then, as its surface falls, so will float I; which thus leaving the spindle of valve H, that valve opens; and then the water flows from cistern F into cylinder E, which, when full, descends, raises lever B A, and opens the sluice.—Again, suppose the water to rise in the aqueduct, the float I rising with it, shuts valve H; when cylinder E is emptied by the small aperture in its bottom, and the weight of lever A B again shuts the sluice. This sluice also acts as a waster, by having a pipe to communicate between the reservoir and cylinder E in the same manner as in figure 4.

A sluice of this description was erected at Rothsay in 1821. Sluice A is three feet long and eighteen inches deep; lever A B three feet long; cylinder E two and a half feet diameter, and the same depth. The depth of water above the centre of the sluice, when the reservoir is full, is twenty feet.

By this contrivance, of making the sluice turn on its centre of pressure, the weight of the column of water resting on it is neutralised; it being at the same time equally exerted to open and shut the sluice. The acting power has, therefore, only to overcome the friction, to make it move in any direction; whereas in the apparatus figure 4 the power must not only overcome the friction, but must also be equal to half the weight of the whole column of water pressing upon the sluice.*

* The other half is borne by the pivots on which the sluice turns. When the sluice is hinged at the upper side, the power has rather more than half the weight to sustain, and when hinged at the under side it has rather less; but where the depth of the sluice bears so small a proportion to the depth of water above it, the difference is not worth noticing in practice.

Thus, in the present case, there is a column of 90 cubic feet of water pressing upon the sluice when the reservoir is full.—Were the sluice hinged upon one side, as in figure 4, it would require the cylinder E to contain forty-five cubic feet of water, besides about one tenth more for friction; and the chain, lever, &c., would have to be made strong in proportion. But by this contrivance the power to act against this forty-five feet of water is wholly saved, and the cylinder requires only to contain water sufficient to overcome the friction.

The apparatus is also simplified by having only one cylinder and one valve, instead of two of each as in fig. 4. But this plan has also some disadvantages. The sluice, when it turns upon pivots at its centre, is more difficult to make water tight than when it turns on pivots at one edge; nor does the same aperture pass an equal quantity of water; for, besides the space occupied by the sluice in the centre, it also tends to disturb the regular flow, or current of the water.

Besides, this apparatus does not operate so *smoothly* as that of figure 4—the can E, and consequently sluice A, moving by starts. After some experience of these and other constructions, the best seems to be, to make the sluice turn on pivots near its centre, as in figure 5, with cylinders and valves as in figure 4. In this way the motion is preserved equally smooth and uniform, as in figure 4; while the power necessary to open and shut the sluice, and consequently the size and expense of the cylinder, is greatly lessened.

THE SINGLE VALVE SLUICE, FIGURE 6.

The construction of this apparatus is, in some respects, similar to those of figures 4 and 5; but its application is to situations where the reservoir is on high grounds, and where the water has to pass down a declivity before it is applied as a power to the mills.

A B, part of the tunnel of a reservoir.

B, a sluice that turns upon pivots, placed a little above its centre of pressure.

C D, the rivulet that carries the water from the reservoir down to

F G, part of a level canal or aqueduct, near the mills.

E H, a hollow cylinder.

K L, a cylinder, waterproof, of rather less specific gravity than water, which moves freely up and down within cylinder E H.

M, a pulley.

B M K, a chain, &c.

I C, a small cistern, kept always full of water by waste from the sluice, or by a small hole in it.

H I, a small pipe, communicating between cistern I C and cylinder E H.

E N, another small pipe, communicating, under ground, between cylinder E H, and

N, a valve at the lower end of pipe E N, which, when open, is capable of passing more water than the pipe H I can receive.

R, a float, placed within a small pool of water, on the same level as, and communicating with the canal.

The water in the canal is here represented at its greatest height; and the valve N shut, by the float R pressing up the spindle: the cylinder E H is therefore filled with water from the cistern I C; and the sluice B shut by the pressure of the water in the reservoir, there being, by construction, a little more pressure *below* than *above* the pivots. When the surface of the water falls in the canal, the float R falls with it; and then the valve N (falling by its own weight) opens, and empties the cylinder E H; when cylinder K L falls, and opens sluice B, and gives the supply required.

It is therefore of no consequence, in regard to regulating the supply of water, how far the reservoir is from, or how high

above, the level of the works requiring the supply; save that the *length* of the pipe E N must correspond with the *distance*, and its *strength* with the *height* or pressure of the water. It is necessary, however, that the bore of this pipe should be small, particularly where its length is considerable; in order that sluice B may open or shut very soon after valve N opens or shuts, and at the same time require only a small supply of water. Suppose, therefore, the opening into the pipe E N at I to be only a half inch bore, and that the valve N is shut when that pipe is empty, it is evident that the sluice B will not shut till both that pipe and cylinder E H be filled with water; and that the smaller the diameter of that pipe be the sooner will it be filled. The time, therefore, that sluice B takes to shut, after valve N shuts, will always be the same as the time that pipe E N and cylinder E H then take to fill; and to make sluice B take an equal length of time to open after valve N opens, the aperture of that valve must be such as to take an equal length of time to run off the water to the bottom of cylinder E H, while the water is still flowing into the aperture at I, as that aperture takes to fill both cylinder and pipe when valve N is shut.

THE CHAIN SLUICE, FIGURE 7.

This apparatus answers exactly the same purpose as the last; only the construction is different.

In this figure the relative situations of the reservoir and canal, and the construction of sluice A, are the same as in figure 6; and the cylinders and valves, the same as in figure 4; with the addition of

R S, a lever.

S P, a chain.

U, a weight, suspended to the spindle of the valves N and O.

One end of the lever R S is connected with the valve spindle N O, and the other end with the chain S P; the other end of this chain is connected with the float P on the canal X Y below.

When the water in the canal X Y rises, float P also rises and slackens the chain S P; the weight U, then falling, shuts valve O and opens valve N; then the water, passing down tube K C L D, raises cylinder F G, and the pressure of the water in the reservoir shuts sluice A. When the water in the canal falls, float P falling with it, lifts the weight U, and shuts valve N, and opens valve O; and then the cylinder F G, falling with the water in cylinder E D, opens sluice A,—and so on.

This construction may perhaps be adopted with advantage, on account of its cheapness, where the reservoir is very *near* the level canal, but a considerable *height above it;* for a brass wire, one tenth of an inch diameter, will be strong enough for the chain where the distance is short; it having in any case little more to lift than twice its own weight. Figure 6, however, seems better adapted to general purposes.

THE SINGLE WEATHER SLUICE, FIGURE 8.

One of the purposes to which this apparatus is applicable, is to regulate the supply of water between a reservoir and mill, or other works, where the former is at a great distance from, and high above, the latter; where several streams fall into the aqueduct between them; and where the adoption of apparatus figure 6 might be considered too expensive. But it may also be applied to several other useful purposes, as will readily occur to such as may have occasion to adopt it.

A B, part of an aqueduct, (close behind the tunnel of the reservoir,) in which the water is always kept at the same level by an apparatus like that of figure 4 or figure 5, placed upon the tunnel of the reservoir. The communication between this part of the aqueduct and that below is opened or closed at pleasure by

B C, a small sluice, (and several others of the same kind which it is unnecessary to represent here,) that turns upon pivots at C.

fall short a quantity equal to what two sluices can pass, the water in the rivulet I K will have fallen so as not to flow out at aperture 2, and a second can will have become empty, and a second sluice open: when they shall have fallen short a quantity equal to what three sluices can pass, the water in the rivulet I K will have fallen so as not flow out at aperture 1, and a third can will have become empty, and a third sluice open, &c. &c.

In this way the water may be regulated at pleasure; and if a small reservoir were made near the works, to retain the water that flows during the night, (or when the Mills are not at work), not a drop would be lost.* The purpose, however, for which this apparatus was invented was different. Having occasion to cut an aqueduct round the bases of some hills, to collect water and convey it to a reservoir at a considerable distance, I found that to make the aqueduct large enough, to convey all the water *as it fell during floods,* would be very expensive; it therefore occurred to me, that if a part of the water could be detained during floods, and brought away gradually afterwards, a much smaller, and of course much less expensive, aqueduct would answer the purpose. I therefore made a small reservoir at a convenient place; and contrived these sluices, to shut during very heavy rains, and open again as they became lighter, which answered the purpose completely, and was the origin of all these weather sluices.

THE DOUBLE WEATHER SLUICES, FIGURE 9.

This apparatus is so far similar to the last described; but it has a double operation, the sluices first opening, one after another, as the streams increase, until they reach a given height;

* The apparatus figure 6, will accomplish the same thing without this small reservoir, but in most cases (particularly where the elevation of the reservoir above, and its distance from, the works is great,) the expense would be much greater than in this.

it sends down the whole supply from the reservoir; when these streams furnish a part, it sends down the remaining part, whatever it may be; and when these streams furnish the whole supply, it shuts the reservoir entirely: so that the supply of water to the mills is always the same, whether the weather be wet or dry.

To accomplish this, the whole number of sluices (B C) placed on the aqueduct A B, are calculated so as just to pass the whole quantity of water wanted at the mills; and as more or less water is produced by these streams, a greater or lesser number of these sluices will open or shut; so as to keep the quantity at the mills uniformly the same. The number of these sluices will be more or less as the case may require; in this we suppose three, as being sufficient to illustrate the principle.

Let us suppose, then, the weather very dry; the streams between the reservoir and the mills quite dried up; and the sluices B C all open: rain comes, and these streams beginto flow: but the same rains that swell these streams, swell also the rivulet I K; and by the time the first produce a quantity equal to what one sluice (B C) can pass, the last will have risen so as to flow out at aperture 1, thence down pipe L M N into can D E; which shuts sluice B C. When these streams increase, so as to produce as much water as two of the sluices (B C) can pass, then the rivulet I K will have swollen so as to flow out at aperture 2, and thence through P into a second can; which shuts a second sluice: when they increase so as to produce a quantity equal to what three of the sluices (B C) can pass, then the water in the rivulet I K, will have risen so as to flow out at aperture 3, and thence through R into a third can; which shuts a third sluice.

Again: suppose the weather to become fair, and the streams begin to decrease; by the time they fall short a quantity equal to what one sluice (B C) can pass, the water in the rivulet I K will have fallen so as not to flow out at aperture 3, and, of course, one can will be empty, and one sluice open: by the time the

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and then shutting, one after another, as they continue to rise above that height. Again, when the streams begin to fall, the sluices open, one after another, until they (the streams) fall to a certain point; and then again shut, one after another, as they continue to fall below that point: the same continuous *rise* in the streams first opening, and then shutting, all these sluices in succession; and, in like manner, the same continuous *fall* first opening, and then shutting, them in succession.

This apparatus, in whole or in part, may, by a judicious adaptation, be applied to many useful purposes, as will be readily perceived by such as are conversant in these matters; but the object chiefly in view in contriving it was its application to what are termed "Compensation Reservoirs." Suppose, for instance, that it is necessary to form a reservoir on the site of some rivulet or stream, for the purpose of collecting water for some important object; and which water is to be carried away in a direction different from the natural course of the rivulet: it is evident that the proprietors of land or works, on the rivulet *below where the proposed reservoir is to be made*, will object to its formation, unless some compensation be made them for the water thus to be carried away. There may be many ways of making such compensation: for the sake of illustration, suppose the following. The proprietors agree that such reservoir may be made, providing that only the surplus water of floods be detained therein, and that all the rest shall be allowed to flow down the rivulet as formerly: that is, all the water necessary for such proprietors shall be allowed to flow down the rivulet, *whilst it produces that quantity*; and when it ceases to produce *that quantity*, they are to have *all that it does produce*, the same as if no such reservoir were there.

The usual way of accomplishing this, is to cut an aqueduct round one side of the reservoir, along which the water of the rivulet is always carried past the reservoir, except during floods, when the surplus water is allowed to flow *over into it*. A little

consideration will shew that a very great quantity of water is thus lost. In the first place, the proprietors below must have all they require before any is allowed to flow over into the reservoir: but the rise of water in the rivulet, that sends a párt *over* into the reservoir, must also send an additional quantity *down* the aqueduct: this additional quantity sent down is therefore lost. But in all such situations, there must be other small streams falling into the rivulet, between the reservoir and works below; and the same rains that swell the rivulet above the reservoir will also swell the streams below it; and consequently the whole additional water yielded by these streams is also lost.*— As the quantity of water thus wasted is generally much greater than that detained in the reservoir; and as the apparatus about to be described saves the whole, its importance may be easily conceived.

But, besides this, the proprietors on the rivulet below generally stipulate to have a certain supply of water from the reservoir, *during the dry season*, as a *bonus* for allowing the reservoir to be made; and as the regulating of this supply has heretofore been left to water-men, who, independent of neglect, caprice, or ignorance, are liable to be biassed by various considerations; and whose conduct, as is well known, has frequently occasioned vexatious disputes and litigation between the parties concerned; it becomes extremely desirable to be independent of such agents. This apparatus, *by regulating such supply of itself*, does away all this; and the quantity, once agreed upon, will continue regular and uniform.

* To explain this more fully, let A B Z represent the course of the rivulet upon which the reservoir C D E is to be formed; A F B, the aqueduct to carry the usual water of the rivulet past the reservoir; Z, the mill or other work, on the rivulet below the reservoir, *which requires the greatest quantity of water;* (and of course when it is supplied all the others must be so;) G, H, I, K, streams that fall into the rivulet between the reservoir and mill Z; L, a part of the bank of the aqueduct A B, lower than the rest, over which the surplus

F G, a pipe which communicates between that cistern and cylinder E.

H, a valve that opens or shuts that communication.

I, a float that rises and falls with the water in the aqueduct.

The sluice A is here represented shut, and the water in the aqueduct at rest. But suppose a part of the water to be drawn from the aqueduct, then, as its surface falls, so will float I; which thus leaving the spindle of valve H, that valve opens; and then the water flows from cistern F into cylinder E, which, when full, descends, raises lever B A, and opens the sluice.—Again, suppose the water to rise in the aqueduct, the float I rising with it, shuts valve H; when cylinder E is emptied by the small aperture in its bottom, and the weight of lever A B again shuts the sluice. This sluice also acts as a waster, by having a pipe to communicate between the reservoir and cylinder E in the same manner as in figure 4.

A sluice of this description was erected at Rothsay in 1821. Sluice A is three feet long and eighteen inches deep; lever A B three feet long; cylinder E two and a half feet diameter, and the same depth. The depth of water above the centre of the sluice, when the reservoir is full, is twenty feet.

By this contrivance, of making the sluice turn on its centre of pressure, the weight of the column of water resting on it is neutralised; it being at the same time equally exerted to open and shut the sluice. The acting power has, therefore, only to overcome the friction, to make it move in any direction; whereas in the apparatus figure 4 the power must not only overcome the friction, but must also be equal to half the weight of the whole column of water pressing upon the sluice.*

* The other half is borne by the pivots on which the sluice turns. When the sluice is hinged at the upper side, the power has rather more than half the weight to sustain, and when hinged at the under side it has rather less; but where the depth of the sluice bears so small a proportion to the depth of water above it, the difference is not worth noticing in practice.

Thus, in the present case, there is a column of 90 cubic feet of water pressing upon the sluice when the reservoir is full.—Were the sluice hinged upon one side, as in figure 4, it would require the cylinder E to contain forty-five cubic feet of water, besides about one tenth more for friction; and the chain, lever, &c., would have to be made strong in proportion. But by this contrivance the power to act against this forty-five feet of water is wholly saved, and the cylinder requires only to contain water sufficient to overcome the friction.

The apparatus is also simplified by having only one cylinder and one valve, instead of two of each as in fig. 4. But this plan has also some disadvantages. The sluice, when it turns upon pivots at its centre, is more difficult to make water tight than when it turns on pivots at one edge; nor does the same aperture pass an equal quantity of water; for, besides the space occupied by the sluice in the centre, it also tends to disturb the regular flow, or current of the water.

Besides, this apparatus does not operate so *smoothly* as that of figure 4—the can E, and consequently sluice A, moving by starts. After some experience of these and other constructions, the best seems to be, to make the sluice turn on pivots near its centre, as in figure 5, with cylinders and valves as in figure 4. In this way the motion is preserved equally smooth and uniform, as in figure 4; while the power necessary to open and shut the sluice, and consequently the size and expense of the cylinder, is greatly lessened.

THE SINGLE VALVE SLUICE, FIGURE 6.

The construction of this apparatus is, in some respects, similar to those of figures 4 and 5; but its application is to situations where the reservoir is on high grounds, and where the water has to pass down a declivity before it is applied as a power to the mills.

A B, part of the tunnel of a reservoir.

B, a sluice that turns upon pivots, placed a little above its centre of pressure.

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F G, part of a level canal or aqueduct, near the mills.

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E N, another small pipe, communicating, under ground, between cylinder E H, and

N, a valve at the lower end of pipe E N, which, when open, is capable of passing more water than the pipe H I can receive.

R, a float, placed within a small pool of water, on the same level as, and communicating with the canal.

The water in the canal is here represented at its greatest height; and the valve N shut, by the float R pressing up the spindle: the cylinder E H is therefore filled with water from the cistern I C; and the sluice B shut by the pressure of the water in the reservoir, there being, by construction, a little more pressure *below* than *above* the pivots. When the surface of the water falls in the canal, the float R falls with it; and then the valve N (falling by its own weight) opens, and empties the cylinder E H; when cylinder K L falls, and opens sluice B, and gives the supply required.

It is therefore of no consequence, in regard to regulating the supply of water, how far the reservoir is from, or how high

above, the level of the works requiring the supply; save that the *length* of the pipe E N must correspond with the *distance*, and its *strength* with the *height* or pressure of the water. It is necessary, however, that the bore of this pipe should be small, particularly where its length is considerable; in order that sluice B may open or shut very soon after valve N opens or shuts, and at the same time require only a small supply of water. Suppose, therefore, the opening into the pipe E N at I to be only a half inch bore, and that the valve N is shut when that pipe is empty, it is evident that the sluice B will not shut till both that pipe and cylinder E H be filled with water; and that the smaller the diameter of that pipe the sooner will it be filled. The time, therefore, that sluice B takes to shut, after valve N shuts, will always be the same as the time that pipe E N and cylinder E H then take to fill; and to make sluice B take an equal length of time to open after valve N opens, the aperture of that valve must be such as to take an equal length of time to run off the water to the bottom of cylinder E H, while the water is still flowing into the aperture at I, as that aperture takes to fill both cylinder and pipe when valve N is shut.

THE CHAIN SLUICE, FIGURE 7.

This apparatus answers exactly the same purpose as the last; only the construction is different.

In this figure the relative situations of the reservoir and canal, and the construction of sluice A, are the same as in figure 6; and the cylinders and valves, the same as in figure 4; with the addition of

R S, a lever.

S P, a chain.

U, a weight, suspended to the spindle of the valves N and O.

One end of the lever R S is connected with the valve spindle N O, and the other end with the chain S P; the other end of this chain is connected with the float P on the canal X Y below.

When the water in the canal X Y rises, float P also rises and slackens the chain S P; the weight U, then falling, shuts valve O and opens valve N; then the water, passing down tube K C L D, raises cylinder F G, and the pressure of the water in the reservoir shuts sluice A. When the water in the canal falls, float P falling with it, lifts the weight U, and shuts valve N, and opens valve O; and then the cylinder F G, falling with the water in cylinder E D, opens sluice A,—and so on.

This construction may perhaps be adopted with advantage, on account of its cheapness, where the reservoir is very *near* the level canal, but a considerable *height above it;* for a brass wire, one tenth of an inch diameter, will be strong enough for the chain where the distance is short; it having in any case little more to lift than twice its own weight. Figure 6, however, seems better adapted to general purposes.

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One of the purposes to which this apparatus is applicable, is to regulate the supply of water between a reservoir and mill, or other works, where the former is at a great distance from, and high above, the latter; where several streams fall into the aqueduct between them; and where the adoption of apparatus figure 6 might be considered too expensive. But it may also be applied to several other useful purposes, as will readily occur to such as may have occasion to adopt it.

A B, part of an aqueduct, (close behind the tunnel of the reservoir,) in which the water is always kept at the same level by an apparatus like that of figure 4 or figure 5, placed upon the tunnel of the reservoir. The communication between this part of the aqueduct and that below is opened or closed at pleasure by

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REPORT

TO SIR MICHAEL SHAW STEWART, BART.

On Supplying Greenock with Water.

BY ROBERT THOM, CIVIL ENGINEER.

Sir,—Agreeably to your request I have inspected the grounds and streams in the vicinity of Greenock, in order to ascertain the resources they afford for supplying that Town with water.

A plentiful supply for this town and its public works, *as they exist at present*, is a matter of comparatively easy accomplishment; but as you also expressed a desire to learn whether a supply to a still greater extent might not be obtained, my attention has been directed accordingly.*

* In justice to a public spirited gentleman, it may be proper here to mention certain circumstances in connection with the origin of the undertaking.

In 1820, when coursing together in Bute, and passing some of the aqueducts there, Mr Geo. Robertson mentioned to Mr Thom the great scarcity of Water in Greenock, and asked if he thought a supply could be procured for it in the same way he had obtained the supply for Rothsay Mills. Mr Thom replied that he had no doubt but something in that way might be done; and asked Mr Robertson respecting the various streams in the vicinity of Greenock. Mr Robertson explained as to these; and mentioned particularly the Shaws Water, and its localities; from which Mr Thom inferred that this stream might be carried to Greenock, and said so to Mr Robertson at the time.

Mr Robertson having mentioned this to some of his friends, and particularly to Sir M. S. Stewart, Mr Thom was applied to in 1821 to inspect the grounds and streams in the vicinity of Greenock, to ascertain the practicability of procuring the necessary supply. But Mr Thom being much occupied by the water and other operations at Rothsay mills, could not then afford the necessary time; on which account some other engineers were employed, who reported that the scheme was impracticable. Early in 1824 Mr Thom was

it sends down the whole supply from the reservoir; when these streams furnish a part, it sends down the remaining part, whatever it may be; and when these streams furnish the whole supply, it shuts the reservoir entirely: so that the supply of water to the mills is always the same, whether the weather be wet or dry.

To accomplish this, the whole number of sluices (B C) placed on the aqueduct A B, are calculated so as just to pass the whole quantity of water wanted at the mills; and as more or less water is produced by these streams, a greater or lesser number of these sluices will open or shut; so as to keep the quantity at the mills uniformly the same. The number of these sluices will be more or less as the case may require; in this we suppose three, as being sufficient to illustrate the principle.

Let us suppose, then, the weather very dry; the streams between the reservoir and the mills quite dried up; and the sluices B C all open: rain comes, and these streams beginto flow: but the same rains that swell these streams, swell also the rivulet I K; and by the time the first produce a quantity equal to what one sluice (B C) can pass, the last will have risen so as to flow out at aperture 1, thence down pipe L M N into can D E; which shuts sluice B C. When these streams increase, so as to produce as much water as two of the sluices (B C) can pass, then the rivulet I K will have swollen so as to flow out at aperture 2, and thence through P into a second can; which shuts a second sluice: when they increase so as to produce a quantity equal to what three of the sluices (B C) can pass, then the water in the rivulet I K, will have risen so as to flow out at aperture 3, and thence through R into a third can; which shuts a third sluice.

Again: suppose the weather to become fair, and the streams begin to decrease; by the time they fall short a quantity equal to what one sluice (B C) can pass, the water in the rivulet I K will have fallen so as not to flow out at aperture 3, and, of course, one can will be empty, and one sluice open: by the time the

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In this way the water may be regulated at pleasure; and if a small reservoir were made near the works, to retain the water that flows during the night, (or when the Mills are not at work), not a drop would be lost.* The purpose, however, for which this apparatus was invented was different. Having occasion to cut an aqueduct round the bases of some hills, to collect water and convey it to a reservoir at a considerable distance, I found that to make the aqueduct large enough, to convey all the water *as it fell during floods*, would be very expensive; it therefore occurred to me, that if a part of the water could be detained during floods, and brought away gradually afterwards, a much smaller, and of course much less expensive, aqueduct would answer the purpose. I therefore made a small reservoir at a convenient place; and contrived these sluices, to shut during very heavy rains, and open again as they became lighter, which answered the purpose completely, and was the origin of all these weather sluices.

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E

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H, a valve that opens or shuts that communication.

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The sluice A is here represented shut, and the water in the aqueduct at rest. But suppose a part of the water to be drawn from the aqueduct, then, as its surface falls, so will float I; which thus leaving the spindle of valve H, that valve opens; and then the water flows from cistern F into cylinder E, which, when full, descends, raises lever B A, and opens the sluice.—Again, suppose the water to rise in the aqueduct, the float I rising with it, shuts valve H; when cylinder E is emptied by the small aperture in its bottom, and the weight of lever A B again shuts the sluice. This sluice also acts as a waster, by having a pipe to communicate between the reservoir and cylinder E in the same manner as in figure 4.

A sluice of this description was erected at Rothsay in 1821. Sluice A is three feet long and eighteen inches deep; lever A B three feet long; cylinder E two and a half feet diameter, and the same depth. The depth of water above the centre of the sluice, when the reservoir is full, is twenty feet.

By this contrivance, of making the sluice turn on its centre of pressure, the weight of the column of water resting on it is neutralised; it being at the same time equally exerted to open and shut the sluice. The acting power has, therefore, only to overcome the friction, to make it move in any direction; whereas in the apparatus figure 4 the power must not only overcome the friction, but must also be equal to half the weight of the whole column of water pressing upon the sluice.*

* The other half is borne by the pivots on which the sluice turns. When the sluice is hinged at the upper side, the power has rather more than half the weight to sustain, and when hinged at the under side it has rather less; but where the depth of the sluice bears so small a proportion to the depth of water above it, the difference is not worth noticing in practice.

Thus, in the present case, there is a column of 90 cubic feet of water pressing upon the sluice when the reservoir is full.—Were the sluice hinged upon one side, as in figure 4, it would require the cylinder E to contain forty-five cubic feet of water, besides about one tenth more for friction; and the chain, lever, &c., would have to be made strong in proportion. But by this contrivance the power to act against this forty-five feet of water is wholly saved, and the cylinder requires only to contain water sufficient to overcome the friction.

The apparatus is also simplified by having only one cylinder and one valve, instead of two of each as in fig. 4. But this plan has also some disadvantages. The sluice, when it turns upon pivots at its centre, is more difficult to make water tight than when it turns on pivots at one edge; nor does the same aperture pass an equal quantity of water; for, besides the space occupied by the sluice in the centre, it also tends to disturb the regular flow, or current of the water.

Besides, this apparatus does not operate so *smoothly* as that of figure 4—the can E, and consequently sluice A, moving by starts. After some experience of these and other constructions, the best seems to be, to make the sluice turn on pivots near its centre, as in figure 5, with cylinders and valves as in figure 4. In this way the motion is preserved equally smooth and uniform, as in figure 4; while the power necessary to open and shut the sluice, and consequently the size and expense of the cylinder, is greatly lessened.

THE SINGLE VALVE SLUICE, FIGURE 6.

The construction of this apparatus is, in some respects, similar to those of figures 4 and 5; but its application is to situations where the reservoir is on high grounds, and where the water has to pass down a declivity before it is applied as a power to the mills.

When the water in the canal X Y rises, float P also rises and slackens the chain S P; the weight U, then falling, shuts valve O and opens valve N; then the water, passing down tube K C L D, raises cylinder F G, and the pressure of the water in the reservoir shuts sluice A. When the water in the canal falls, float P falling with it, lifts the weight U, and shuts valve N, and opens valve O; and then the cylinder F G, falling with the water in cylinder E D, opens sluice A,—and so on.

This construction may perhaps be adopted with advantage, on account of its cheapness, where the reservoir is very *near* the level canal, but a considerable *height above it;* for a brass wire, one tenth of an inch diameter, will be strong enough for the chain where the distance is short; it having in any case little more to lift than twice its own weight. Figure 6, however, seems better adapted to general purposes.

THE SINGLE WEATHER SLUICE, FIGURE 8.

One of the purposes to which this apparatus is applicable, is to regulate the supply of water between a reservoir and mill, or other works, where the former is at a great distance from, and high above, the latter; where several streams fall into the aqueduct between them; and where the adoption of apparatus figure 6 might be considered too expensive. But it may also be applied to several other useful purposes, as will readily occur to such as may have occasion to adopt it.

A B, part of an aqueduct, (close behind the tunnel of the reservoir,) in which the water is always kept at the same level by an apparatus like that of figure 4 or figure 5, placed upon the tunnel of the reservoir. The communication between this part of the aqueduct and that below is opened or closed at pleasure by

B C, a small sluice, (and several others of the same kind which it is unnecessary to represent here,) that turns upon pivots at C.

neration more to the *effects* which must *follow* the successful establishment of such works than to any *direct* return from the *works themselves.* All narrow and immediately selfish views must be entirely kept out of view: for the least appearance of such will prevent persons of skill and capital* from closing:—

> " For *Trade* in *biting* climates will not grow,
> " Unless, like orange trees, 'tis housed from snow!"

In my estimate I have taken no notice of the rent to be paid for the grounds to be covered or flooded by the reservoir, and through which the aqueduct passes; but it cannot be much, as the proprietors are understood to be friendly to the measure, and the lands very poor; probably not worth, upon an average, ten shillings an acre annually; nor is it necessary to purchase or feu such grounds; a servitude over them for that purpose being quite sufficient.

The reservoir, when full, will cover above two hundred Scotch acres, partly upon the lands of Ardgowan, and partly on those of Gourock and Garvock.† From the estimate it will be observed that several small reservoirs are to be made above the aqueduct, having self-acting sluices to retain, during floods, the water from the hills, which would otherwise overflow the aqueduct and be lost. There are also self-acting sluices to be placed upon the large reservoir, to retain the water there, when enough for the works is obtained from the rivulets, on the face of the hills, *between* the reservoir and Greenock. In this way I cal-

* It is only persons of skill and capital that *should* be encouraged to establish works here. Needy adventurers will grasp at *any* thing, and almost on any terms: but what would be the result? Not only a complete failure in the first instance, but the difficulties for the future greatly augmented; for every one is aware of the paralysing effects of a first failure.—See Note 5th.

† It was afterwards determined to raise the embankment about four feet higher, which has been done; and now (1828) the reservoir covers 294¾ imperial acres, and contains something above 284,000,000 millions of cubic feet of water.

it sends down the whole supply from the reservoir; when these streams furnish a part, it sends down the remaining part, whatever it may be; and when these streams furnish the whole supply, it shuts the reservoir entirely: so that the supply of water to the mills is always the same, whether the weather be wet or dry.

To accomplish this, the whole number of sluices (B C) placed on the aqueduct A B, are calculated so as just to pass the whole quantity of water wanted at the mills; and as more or less water is produced by these streams, a greater or lesser number of these sluices will open or shut; so as to keep the quantity at the mills uniformly the same. The number of these sluices will be more or less as the case may require; in this we suppose three, as being sufficient to illustrate the principle.

Let us suppose, then, the weather very dry; the streams between the reservoir and the mills quite dried up; and the sluices B C all open: rain comes, and these streams beginto flow: but the same rains that swell these streams, swell also the rivulet I K; and by the time the first produce a quantity equal to what one sluice (B C) can pass, the last will have risen so as to flow out at aperture 1, thence down pipe L M N into can D E; which shuts sluice B C. When these streams increase, so as to produce as much water as two of the sluices (B C) can pass, then the rivulet I K will have swollen so as to flow out at aperture 2, and thence through P into a second can; which shuts a second sluice: when they increase so as to produce a quantity equal to what three of the sluices (B C) can pass, then the water in the rivulet I K, will have risen so as to flow out at aperture 3, and thence through R into a third can; which shuts a third sluice.

Again: suppose the weather to become fair, and the streams begin to decrease; by the time they fall short a quantity equal to what one sluice (B C) can pass, the water in the rivulet I K will have fallen so as not to flow out at aperture 3, and, of course, one can will be empty, and one sluice open: by the time the

fall short a quantity equal to what two sluices can pass, the water in the rivulet I K will have fallen so as not to flow out at aperture 2, and a second can will have become empty, and a second sluice open: when they shall have fallen short a quantity equal to what three sluices can pass, the water in the rivulet I K will have fallen so as not flow out at aperture 1, and a third can will have become empty, and a third sluice open, &c. &c.

In this way the water may be regulated at pleasure; and if a small reservoir were made near the works, to retain the water that flows during the night, (or when the Mills are not at work), not a drop would be lost.* The purpose, however, for which this apparatus was invented was different. Having occasion to cut an aqueduct round the bases of some hills, to collect water and convey it to a reservoir at a considerable distance, I found that to make the aqueduct large enough, to convey all the water *as it fell during floods*, would be very expensive; it therefore occurred to me, that if a part of the water could be detained during floods, and brought away gradually afterwards, a much smaller, and of course much less expensive, aqueduct would answer the purpose. I therefore made a small reservoir at a convenient place; and contrived these sluices, to shut during very heavy rains, and open again as they became lighter, which answered the purpose completely, and was the origin of all these weather sluices.

THE DOUBLE WEATHER SLUICES, FIGURE 9.

This apparatus is so far similar to the last described; but it has a double operation, the sluices first opening, one after another, as the streams increase, until they reach a given height;

* The apparatus figure 6, will accomplish the same thing without this small reservoir, but in most cases (particularly where the elevation of the reservoir above, and its distance from, the works is great,) the expense would be much greater than in this.

F G, a pipe which communicates between that cistern and cylinder E.

H, a valve that opens or shuts that communication.

I, a float that rises and falls with the water in the aqueduct.

The sluice A is here represented shut, and the water in the aqueduct at rest. But suppose a part of the water to be drawn from the aqueduct, then, as its surface falls, so will float I; which thus leaving the spindle of valve H, that valve opens; and then the water flows from cistern F into cylinder E, which, when full, descends, raises lever B A, and opens the sluice.—Again, suppose the water to rise in the aqueduct, the float I rising with it, shuts valve H; when cylinder E is emptied by the small aperture in its bottom, and the weight of lever A B again shuts the sluice. This sluice also acts as a waster, by having a pipe to communicate between the reservoir and cylinder E in the same manner as in figure 4.

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By this contrivance, of making the sluice turn on its centre of pressure, the weight of the column of water resting on it is neutralised; it being at the same time equally exerted to open and shut the sluice. The acting power has, therefore, only to overcome the friction, to make it move in any direction; whereas in the apparatus figure 4 the power must not only overcome the friction, but must also be equal to half the weight of the whole column of water pressing upon the sluice.*

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Thus, in the present case, there is a column of 90 cubic feet of water pressing upon the sluice when the reservoir is full.—Were the sluice hinged upon one side, as in figure 4, it would require the cylinder E to contain forty-five cubic feet of water, besides about one tenth more for friction; and the chain, lever, &c., would have to be made strong in proportion. But by this contrivance the power to act against this forty-five feet of water is wholly saved, and the cylinder requires only to contain water sufficient to overcome the friction.

The apparatus is also simplified by having only one cylinder and one valve, instead of two of each as in fig. 4. But this plan has also some disadvantages. The sluice, when it turns upon pivots at its centre, is more difficult to make water tight than when it turns on pivots at one edge; nor does the same aperture pass an equal quantity of water; for, besides the space occupied by the sluice in the centre, it also tends to disturb the regular flow, or current of the water.

Besides, this apparatus does not operate so *smoothly* as that of figure 4—the can E, and consequently sluice A, moving by starts. After some experience of these and other constructions, the best seems to be, to make the sluice turn on pivots near its centre, as in figure 5, with cylinders and valves as in figure 4. In this way the motion is preserved equally smooth and uniform, as in figure 4; while the power necessary to open and shut the sluice, and consequently the size and expense of the cylinder, is greatly lessened.

THE SINGLE VALVE SLUICE, FIGURE 6.

The construction of this apparatus is, in some respects, similar to those of figures 4 and 5; but its application is to situations where the reservoir is on high grounds, and where the water has to pass down a declivity before it is applied as a power to the mills.

A B, part of the tunnel of a reservoir.

B, a sluice that turns upon pivots, placed a little above its centre of pressure.

C D, the rivulet that carries the water from the reservoir down to

F G, part of a level canal or aqueduct, near the mills.

E H, a hollow cylinder.

K L, a cylinder, waterproof, of rather less specific gravity than water, which moves freely up and down within cylinder E H.

M, a pulley.

B M K, a chain, &c.

I C, a small cistern, kept always full of water by waste from the sluice, or by a small hole in it.

H I, a small pipe, communicating between cistern I C and cylinder E H.

E N, another small pipe, communicating, under ground, between cylinder E H, and

N, a valve at the lower end of pipe E N, which, when open, is capable of passing more water than the pipe H I can receive.

R, a float, placed within a small pool of water, on the same level as, and communicating with the canal.

The water in the canal is here represented at its greatest height; and the valve N shut, by the float R pressing up the spindle: the cylinder E H is therefore filled with water from the cistern I C; and the sluice B shut by the pressure of the water in the reservoir, there being, by construction, a little more pressure *below* than *above* the pivots. When the surface of the water falls in the canal, the float R falls with it; and then the valve N (falling by its own weight) opens, and empties the cylinder E H; when cylinder K L falls, and opens sluice B, and gives the supply required.

It is therefore of no consequence, in regard to regulating the supply of water, how far the reservoir is from, or how high

above, the level of the works requiring the supply; save that the *length* of the pipe E N must correspond with the *distance*, and its *strength* with the *height* or pressure of the water. It is necessary, however, that the bore of this pipe should be small, particularly where its length is considerable; in order that sluice B may open or shut very soon after valve N opens or shuts, and at the same time require only a small supply of water. Suppose, therefore, the opening into the pipe E N at I to be only a half inch bore, and that the valve N is shut when that pipe is empty, it is evident that the sluice B will not shut till both that pipe and cylinder E H be filled with water; and that the smaller the diameter of that pipe be the sooner will it be filled. The time, therefore, that sluice B takes to shut, after valve N shuts, will always be the same as the time that pipe E N and cylinder E H then take to fill; and to make sluice B take an equal length of time to open after valve N opens, the aperture of that valve must be such as to take an equal length of time to run off the water to the bottom of cylinder E H, while the water is still flowing into the aperture at I, as that aperture takes to fill both cylinder and pipe when valve N is shut.

THE CHAIN SLUICE, FIGURE 7.

This apparatus answers exactly the same purpose as the last; only the construction is different.

In this figure the relative situations of the reservoir and canal, and the construction of sluice A, are the same as in figure 6; and the cylinders and valves, the same as in figure 4; with the addition of

R S, a lever.

S P, a chain.

U, a weight, suspended to the spindle of the valves N and O.

One end of the lever R S is connected with the valve spindle N O, and the other end with the chain S P; the other end of this chain is connected with the float P on the canal X Y below.

When the water in the canal X Y rises, float P also rises and slackens the chain S P; the weight U, then falling, shuts valve O and opens valve N; then the water, passing down tube K C L D, raises cylinder F G, and the pressure of the water in the reservoir shuts sluice A. When the water in the canal falls, float P falling with it, lifts the weight U, and shuts valve N, and opens valve O; and then the cylinder F G, falling with the water in cylinder E D, opens sluice A,—and so on.

This construction may perhaps be adopted with advantage, on account of its cheapness, where the reservoir is very *near* the level canal, but a considerable *height above it;* for a brass wire, one tenth of an inch diameter, will be strong enough for the chain where the distance is short; it having in any case little more to lift than twice its own weight. Figure 6, however, seems better adapted to general purposes.

THE SINGLE WEATHER SLUICE, FIGURE 8.

One of the purposes to which this apparatus is applicable, is to regulate the supply of water between a reservoir and mill, or other works, where the former is at a great distance from, and high above, the latter; where several streams fall into the aqueduct between them; and where the adoption of apparatus figure 6 might be considered too expensive. But it may also be applied to several other useful purposes, as will readily occur to such as may have occasion to adopt it.

A B, part of an aqueduct, (close behind the tunnel of the reservoir,) in which the water is always kept at the same level by an apparatus like that of figure 4 or figure 5, placed upon the tunnel of the reservoir. The communication between this part of the aqueduct and that below is opened or closed at pleasure by

B C, a small sluice, (and several others of the same kind which it is unnecessary to represent here,) that turns upon pivots at C.

It is only necessary, therefore, to hold out and grant terms so advantageous in other respects as would compensate these disadvantages, and induce persons of skill and capital to embark in such works, and, as already observed, *no others should be encouraged to do so.* Nor would the advantageous terms thus granted prove more beneficial to the manufacturer, than to the Lord of the Manor, and the other proprietors of land in the vicinity. When periods of dull trade occur—and they will occur occasionally, whilst trade itself exists—it is usual for many such works to be stopped, and the starving population thrown for support upon the property around them. Now, whatever may be the *cause* of this dull trade, there can be no doubt that its bad effects are greatly increased by *panic ;* and that manufacturers, who know that they carry on their business to disadvantage, as compared with others, are naturally the most easily as well as most seriously alarmed, and the first to throw their hands idle; whereas an establishment, knowing that it really *does* possess considerable advantages, will, *particularly if it employs many hands,* carry on, even if it should be to a loss for a time,—well knowing that it must *in the end* swim, if others should sink.

It is, therefore, of the utmost importance to all having property in the vicinity of public works—particularly in the vicinity of those employing many hands—that such works should be possessed of as many advantages as possible; *for it is only the knowledge of being possessed of such advantages that can protect them from the general panic, and enable them to carry on their works while others are stopped.* And if a work, employing many hands, really *does* possess such advantages, and its owners be possessed of the requisite *skill* and *capital,* they will find it *their interest* to keep their hands always employed. Such works may, therefore, be calculated upon with confidence, to go on *steadily even in the worst of times.* To satisfy ourselves that this reasoning is just, we have only to look around us to see many striking and pleasing examples. Hence Proprietors of the soil, who, in

it sends down the whole supply from the reservoir; when these streams furnish a part, it sends down the remaining part, whatever it may be; and when these streams furnish the whole supply, it shuts the reservoir entirely: so that the supply of water to the mills is always the same, whether the weather be wet or dry.

To accomplish this, the whole number of sluices (B C) placed on the aqueduct A B, are calculated so as just to pass the whole quantity of water wanted at the mills; and as more or less water is produced by these streams, a greater or lesser number of these sluices will open or shut; so as to keep the quantity at the mills uniformly the same. The number of these sluices will be more or less as the case may require; in this we suppose three, as being sufficient to illustrate the principle.

Let us suppose, then, the weather very dry; the streams between the reservoir and the mills quite dried up; and the sluices B C all open: rain comes, and these streams beginto flow: but the same rains that swell these streams, swell also the rivulet I K; and by the time the first produce a quantity equal to what one sluice (B C) can pass, the last will have risen so as to flow out at aperture 1, thence down pipe L M N into can D E; which shuts sluice B C. When these streams increase, so as to produce as much water as two of the sluices (B C) can pass, then the rivulet I K will have swollen so as to flow out at aperture 2, and thence through P into a second can; which shuts a second sluice: when they increase so as to produce a quantity equal to what three of the sluices (B C) can pass, then the water in the rivulet I K, will have risen so as to flow out at aperture 3, and thence through R into a third can; which shuts a third sluice.

Again: suppose the weather to become fair, and the streams begin to decrease; by the time they fall short a quantity equal to what one sluice (B C) can pass, the water in the rivulet I K will have fallen so as not to flow out at aperture 3, and, of course, one can will be empty, and one sluice open: by the time the

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Thus, in the present case, there is a column of 90 cubic feet of water pressing upon the sluice when the reservoir is full.— Were the sluice hinged upon one side, as in figure 4, it would require the cylinder E to contain forty-five cubic feet of water, besides about one tenth more for friction; and the chain, lever, &c., would have to be made strong in proportion. But by this contrivance the power to act against this forty-five feet of water is wholly saved, and the cylinder requires only to contain water sufficient to overcome the friction.

The apparatus is also simplified by having only one cylinder and one valve, instead of two of each as in fig. 4. But this plan has also some disadvantages. The sluice, when it turns upon pivots at its centre, is more difficult to make water tight than when it turns on pivots at one edge; nor does the same aperture pass an equal quantity of water; for, besides the space occupied by the sluice in the centre, it also tends to disturb the regular flow, or current of the water.

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R, a float, placed within a small pool of water, on the same level as, and communicating with the canal.

The water in the canal is here represented at its greatest height; and the valve N shut, by the float R pressing up the spindle: the cylinder E H is therefore filled with water from the cistern I C; and the sluice B shut by the pressure of the water in the reservoir, there being, by construction, a little more pressure *below* than *above* the pivots. When the surface of the water falls in the canal, the float R falls with it; and then the valve N (falling by its own weight) opens, and empties the cylinder E H; when cylinder K L falls, and opens sluice B, and gives the supply required.

It is therefore of no consequence, in regard to regulating the supply of water, how far the reservoir is from, or how high

above, the level of the works requiring the supply; save that the *length* of the pipe E N must correspond with the *distance*, and its *strength* with the *height* or pressure of the water. It is necessary, however, that the bore of this pipe should be small, particularly where its length is considerable; in order that sluice B may open or shut very soon after valve N opens or shuts, and at the same time require only a small supply of water. Suppose, therefore, the opening into the pipe E N at I to be only a half inch bore, and that the valve N is shut when that pipe is empty, it is evident that the sluice B will not shut till both that pipe and cylinder E H be filled with water; and that the smaller the diameter of that pipe be the sooner will it be filled. The time, therefore, that sluice B takes to shut, after valve N shuts, will always be the same as the time that pipe E N and cylinder E H then take to fill; and to make sluice B take an equal length of time to open after valve N opens, the aperture of that valve must be such as to take an equal length of time to run off the water to the bottom of cylinder E H, while the water is still flowing into the aperture at I, as that aperture takes to fill both cylinder and pipe when valve N is shut.

THE CHAIN SLUICE, FIGURE 7.

This apparatus answers exactly the same purpose as the last; only the construction is different.

In this figure the relative situations of the reservoir and canal, and the construction of sluice A, are the same as in figure 6; and the cylinders and valves, the same as in figure 4; with the addition of

R S, a lever.

S P, a chain.

U, a weight, suspended to the spindle of the valves N and O.

One end of the lever R S is connected with the valve spindle N O, and the other end with the chain S P; the other end of this chain is connected with the float P on the canal X Y below.

When the water in the canal X Y rises, float P also rises and slackens the chain S P; the weight U, then falling, shuts valve O and opens valve N; then the water, passing down tube K C L D, raises cylinder F G, and the pressure of the water in the reservoir shuts sluice A. When the water in the canal falls, float P falling with it, lifts the weight U, and shuts valve N, and opens valve O; and then the cylinder F G, falling with the water in cylinder E D, opens sluice A,—and so on.

This construction may perhaps be adopted with advantage, on account of its cheapness, where the reservoir is very *near* the level canal, but a considerable *height above it;* for a brass wire, one tenth of an inch diameter, will be strong enough for the chain where the distance is short; it having in any case little more to lift than twice its own weight. Figure 6, however, seems better adapted to general purposes.

THE SINGLE WEATHER SLUICE, FIGURE 8.

One of the purposes to which this apparatus is applicable, is to regulate the supply of water between a reservoir and mill, or other works, where the former is at a great distance from, and high above, the latter; where several streams fall into the aqueduct between them; and where the adoption of apparatus figure 6 might be considered too expensive. But it may also be applied to several other useful purposes, as will readily occur to such as may have occasion to adopt it.

A B, part of an aqueduct, (close behind the tunnel of the reservoir,) in which the water is always kept at the same level by an apparatus like that of figure 4 or figure 5, placed upon the tunnel of the reservoir. The communication between this part of the aqueduct and that below is opened or closed at pleasure by

B C, a small sluice, (and several others of the same kind which it is unnecessary to represent here,) that turns upon pivots at C.

lations, or as to the amount of damages arising from any such causes, all such claims shall be referred to Arbitration, in the terms expressed in Article 14th.

XII.

In the event of a fall of snow, so heavy as to obstruct or impede the passage of the Water along the Aqueduct and Mill-Leads, the Company shall furnish, whilst there is only one Mill started, four able workmen for every one such workman furnished by the Mill Proprietors, for the purpose of clearing out the same, with as little delay as possible. When there are two Mills started, then the Company shall furnish three able workmen for every such workman furnished by the Proprietors or Occupiers of the two Mills. When three Mills are started, then the Company shall furnish two men for every three furnished by the Mills; and when four or more Mills are started, the Proprietors themselves of these Mills, on whatever Line they are placed, shall be at the whole trouble and expense of so cleaning the Aqueducts and Leads; only they shall, on every such occasion, give notice of the same to the Clerk or Clerks, or Engineer, of the Company, so that they (the Company) may send a fit person or persons to superintend such operations, in order that no injury may be thereby done to the Aqueducts, Leads, or other property of the Company. The number of men to be furnished for this purpose, by each Mill, to be in proportion to the height of its Fall. The whole number shall be fixed from time to time by the Proprietors of at least a majority of the Mills then started; and what is so fixed shall be binding on the Proprietors and Occupiers of the whole of such Mills. And if the Proprietors or Occupiers of any of the Mills shall fail or neglect to furnish the number of men thus fixed, they shall be liable to the Proprietors or Occupiers of the Mills furnishing their quota, not only in double wages for each deficient man, but also for a sum equal to two days' Water-rent for each day their Mill shall be thereby

it sends down the whole supply from the reservoir; when these streams furnish a part, it sends down the remaining part, whatever it may be; and when these streams furnish the whole supply, it shuts the reservoir entirely: so that the supply of water to the mills is always the same, whether the weather be wet or dry.

To accomplish this, the whole number of sluices (B C) placed on the aqueduct A B, are calculated so as just to pass the whole quantity of water wanted at the mills; and as more or less water is produced by these streams, a greater or lesser number of these sluices will open or shut; so as to keep the quantity at the mills uniformly the same. The number of these sluices will be more or less as the case may require; in this we suppose three, as being sufficient to illustrate the principle.

Let us suppose, then, the weather very dry; the streams between the reservoir and the mills quite dried up; and the sluices B C all open: rain comes, and these streams begin to flow: but the same rains that swell these streams, swell also the rivulet I K; and by the time the first produce a quantity equal to what one sluice (B C) can pass, the last will have risen so as to flow out at aperture 1, thence down pipe L M N into can D E; which shuts sluice B C. When these streams increase, so as to produce as much water as two of the sluices (B C) can pass, then the rivulet I K will have swollen so as to flow out at aperture 2, and thence through P into a second can; which shuts a second sluice: when they increase so as to produce a quantity equal to what three of the sluices (B C) can pass, then the water in the rivulet I K, will have risen so as to flow out at aperture 3, and thence through R into a third can; which shuts a third sluice.

Again: suppose the weather to become fair, and the streams begin to decrease; by the time they fall short a quantity equal to what one sluice (B C) can pass, the water in the rivulet I K will have fallen so as not to flow out at aperture 3, and, of course, one can will be empty, and one sluice open: by the time the

fall short a quantity equal to what two sluices can pass, the water in the rivulet I K will have fallen so as not to flow out at aperture 2, and a second can will have become empty, and a second sluice open: when they shall have fallen short a quantity equal to what three sluices can pass, the water in the rivulet I K will have fallen so as not flow out at aperture 1, and a third can will have become empty, and a third sluice open, &c. &c.

In this way the water may be regulated at pleasure; and if a small reservoir were made near the works, to retain the water that flows during the night, (or when the Mills are not at work), not a drop would be lost.* The purpose, however, for which this apparatus was invented was different. Having occasion to cut an aqueduct round the bases of some hills, to collect water and convey it to a reservoir at a considerable distance, I found that to make the aqueduct large enough, to convey all the water *as it fell during floods*, would be very expensive; it therefore occurred to me, that if a part of the water could be detained during floods, and brought away gradually afterwards, a much smaller, and of course much less expensive, aqueduct would answer the purpose. I therefore made a small reservoir at a convenient place; and contrived these sluices, to shut during very heavy rains, and open again as they became lighter, which answered the purpose completely, and was the origin of all these weather sluices.

THE DOUBLE WEATHER SLUICES, FIGURE 9.

This apparatus is so far similar to the last described; but it has a double operation, the sluices first opening, one after another, as the streams increase, until they reach a given height;

* The apparatus figure 6, will accomplish the same thing without this small reservoir, but in most cases (particularly where the elevation of the reservoir above, and its distance from, the works is great,) the expense would be much greater than in this.

A B, part of the tunnel of a reservoir.

B, a sluice that turns upon pivots, placed a little above its centre of pressure.

C D, the rivulet that carries the water from the reservoir down to

F G, part of a level canal or aqueduct, near the mills.

E H, a hollow cylinder.

K L, a cylinder, waterproof, of rather less specific gravity than water, which moves freely up and down within cylinder E H.

M, a pulley.

B M K, a chain, &c.

I C, a small cistern, kept always full of water by waste from the sluice, or by a small hole in it.

H I, a small pipe, communicating between cistern I C and cylinder E H.

E N, another small pipe, communicating, under ground, between cylinder E H, and

N, a valve at the lower end of pipe E N, which, when open, is capable of passing more water than the pipe H I can receive.

R, a float, placed within a small pool of water, on the same level as, and communicating with the canal.

The water in the canal is here represented at its greatest height; and the valve N shut, by the float R pressing up the spindle: the cylinder E H is therefore filled with water from the cistern I C; and the sluice B shut by the pressure of the water in the reservoir, there being, by construction, a little more pressure *below* than *above* the pivots. When the surface of the water falls in the canal, the float R falls with it; and then the valve N (falling by its own weight) opens, and empties the cylinder E H; when cylinder K L falls, and opens sluice B, and gives the supply required.

It is therefore of no consequence, in regard to regulating the supply of water, how far the reservoir is from, or how high

above, the level of the works requiring the supply; save that the *length* of the pipe E N must correspond with the *distance*, and its *strength* with the *height* or pressure of the water. It is necessary, however, that the bore of this pipe should be small, particularly where its length is considerable; in order that sluice B may open or shut very soon after valve N opens or shuts, and at the same time require only a small supply of water. Suppose, therefore, the opening into the pipe E N at I to be only a half inch bore, and that the valve N is shut when that pipe is empty, it is evident that the sluice B will not shut till both that pipe and cylinder E H be filled with water; and that the smaller the diameter of that pipe be the sooner will it be filled. The time, therefore, that sluice B takes to shut, after valve N shuts, will always be the same as the time that pipe E N and cylinder E H then take to fill; and to make sluice B take an equal length of time to open after valve N opens, the aperture of that valve must be such as to take an equal length of time to run off the water to the bottom of cylinder E H, while the water is still flowing into the aperture at I, as that aperture takes to fill both cylinder and pipe when valve N is shut.

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S P, a chain.

U, a weight, suspended to the spindle of the valves N and O.

One end of the lever R S is connected with the valve spindle N O, and the other end with the chain S P; the other end of this chain is connected with the float P on the canal X Y below.

When the water in the canal X Y rises, float P also rises and slackens the chain S P; the weight U, then falling, shuts valve O and opens valve N; then the water, passing down tube K C L D, raises cylinder F G, and the pressure of the water in the reservoir shuts sluice A. When the water in the canal falls, float P falling with it, lifts the weight U, and shuts valve N, and opens valve O; and then the cylinder F G, falling with the water in cylinder E D, opens sluice A,—and so on.

This construction may perhaps be adopted with advantage, on account of its cheapness, where the reservoir is very *near* the level canal, but a considerable *height above it;* for a brass wire, one tenth of an inch diameter, will be strong enough for the chain where the distance is short; it having in any case little more to lift than twice its own weight. Figure 6, however, seems better adapted to general purposes.

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B C, a small sluice, (and several others of the same kind which it is unnecessary to represent here,) that turns upon pivots at C.

successors, and in the event of the said A B and C D, and their foresaids transgressing in any of the abovementioned prohibitions, either by erecting dwelling-houses or other buildings for habitation, or by converting any buildings into dwelling-houses, or by sub-feuing or conveying with double holdings, then the dispositions or other deeds containing such contravention shall be void and null, and shall confer no right on the disponees, and the person or persons so transgressing shall forfeit all right to the premises, which shall recognosce and fall back to the said Shaws Water Joint Stock Company and their foresaids. But without prejudice to the vassals to grant heritable securities on the premises, redeemable by the granter and his heirs or assignees, with a double holding and with a precept of sasine, which securities and infeftment to follow thereon, shall not be affected by the above prohibitions or irritancy, they being always redeemable, and it being therein declared that in the event of a sale taking place in virtue of any power to be contained in the heritable bond, the disposition to the purchaser shall contain all the conditions and restrictions before specified, otherwise the same and the sale shall become void and null. In which subjects, with the tiends and pertinents, the said Shaws Water Joint Stock Company bind and oblige themselves and their successors, to infeft and seise the said A B and C D, and their foresaids, on their own expenses, to be holden of and under the Shaws Water Joint Stock Company and their foresaids, as immediate, lawful superiors thereof, in feu, farm, and heritage, for ever, for payment of the feu-duty and additional feu-duty after specified, for the said Subjects, and also for payment of the annual duty after specified, for the foresaid privilege of the Water and Water-fall: WHICH Feu Contract and Ground hereby feued, with the use and privilege of the said Water-fall and Water, but under the provisions, conditions, and declarations mentioned and contained in the said Regulations, the said Shaws Water Joint Stock Company bind and oblige themselves to the extent of the Stock of the said Company, to warrant to the said A B and C D, and their foresaids, at all hands.

it sends down the whole supply from the reservoir; when these streams furnish a part, it sends down the remaining part, whatever it may be; and when these streams furnish the whole supply, it shuts the reservoir entirely: so that the supply of water to the mills is always the same, whether the weather be wet or dry.

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Again: suppose the weather to become fair, and the streams begin to decrease; by the time they fall short a quantity equal to what one sluice (B C) can pass, the water in the rivulet I K will have fallen so as not to flow out at aperture 3, and, of course, one can will be empty, and one sluice open: by the time the

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In this way the water may be regulated at pleasure; and if a small reservoir were made near the works, to retain the water that flows during the night, (or when the Mills are not at work), not a drop would be lost.* The purpose, however, for which this apparatus was invented was different. Having occasion to cut an aqueduct round the bases of some hills, to collect water and convey it to a reservoir at a considerable distance, I found that to make the aqueduct large enough, to convey all the water *as it fell during floods*, would be very expensive; it therefore occurred to me, that if a part of the water could be detained during floods, and brought away gradually afterwards, a much smaller, and of course much less expensive, aqueduct would answer the purpose. I therefore made a small reservoir at a convenient place; and contrived these sluices, to shut during very heavy rains, and open again as they became lighter, which answered the purpose completely, and was the origin of all these weather sluices.

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* The apparatus figure 6, will accomplish the same thing without this small reservoir, but in most cases (particularly where the elevation of the reservoir above, and its distance from, the works is great,) the expense would be much greater than in this.

all Courts to be held by their Superiors or their Bailies, upon 24 hours' notice: And farther, the said A B and C D, for themselves, and as Partners foresaid, bind and oblige themselves, and the said Company of A B & Co., and their foresaids, to content and pay to the said Shaws Water Joint Stock Company, and their foresaids, the sum of L. sterling, yearly, as a rate or duty, or ground annual for the use of the foresaid Water-fall, and of the Water passing the same, for the purpose foresaid, and that at two terms of the year, Whitsunday and Martinmas, by equal portions, commencing the first half-yearly payment, at for the half year preceding, and the next payment at thereafter; and so to continue thereafter, with a fifth part further of each term's payment, in case of failure, and interest of each term's payment, from the time the same falls due till payment: And it is hereby specially provided and declared, that the said sum of L. yearly, shall in all time coming, be a real burden on the said Subjects hereby feued, and on the Mills and other Buildings to be erected thereon, and whole Machinery, great and small, to be placed therein, and shall be secured thereon, in the same manner as the foresaid Feu Duty; and these presents are accordingly granted under the real burden of the foresaid sum of L. payable half-yearly, commencing at the foresaid term, with interest and penalty as before described, and all these burdens shall be engrossed in the infeftments to follow hereupon, and on the subsequent Charters, Conveyances, and Infeftments of the said Lands, under the pain of nullity, and these for all other exaction or demand which can be made forth of the premises by the said Shaws Water Joint Stock Company, and their foresaids. Further, the said Shaws Water Joint Stock Company bind and oblige themselves, and the Stock of their said Company, to comply with and fulfil all those parts of the said Regulations incumbent on the said Company: and, in particular, to appoint a proper person to take charge of the opening and shutting of the sluices, and to attend to the other matters specified in the Regulations—declaring that the Company shall not be liable

for damage or loss arising in consequence of a failure of the supply of Water, by inevitable accident or the like, as more fully explained in Article 10th of the said Regulations: And the said A B and C D, and A B, & Co., bind and oblige themselves, and their foresaids, to comply with and fulfill all those parts of the said Regulations incumbent on the Feuars and Occupiers of Mill-steads and Waterfalls, and in particular not to make use of, or divert any of the said Water from the said Cut or Lead, to the prejudice of the Mills below, or to deteriorate the quality of the Water, as above specified. And both parties bind and oblige themselves, and their foresaids, to fulfil and perform their respective parts of the premises to each other, under the penalty of L.200 sterling, to be paid by the party failing, to the party observing, or willing to observe, attour performance: And they consent to the Registration hereof in the Books of Council and Session, or others competent for preservation; and, if necessary, that Letters of Horning, on six days' charge, and all other legal execution, may pass upon a Decree to be interponed hereto, in form as effeirs: And thereto constitute

Procurators, &c., Attour, to the end that the said A B, and C D, and their foresaids, may be infeft and seised in the Subjects before conveyed, the said Shaws Water Joint Stock Company hereby desire and require you, and each of you, their Bailies in that part hereby specially constituted, that on sight hereof, ye pass to the Ground of the said Subjects, and there give and deliver to the said A B and C D, partners in trade, under the said firm, and their foresaids, heritable state and sasine, real, actual, and corporal possession of all and whole the foresaid lot of ground marked No. on the Plan before mentioned, consisting of old Scots measure, or thereby, lying, as before specified, and here held as repeated, with the Tiends and Pertinents thereof, and the privilege of the Water-fall and use of the Water, for the purposes and under the Regulations before-mentioned, all as more particularly described before, and in the Regulations hereto appended, and here held as repeated, but under

the burden of payment of the Feu Duty, additional Feu Duties, and other stipulations before specified, and also under the real burden of paying the foresaid sum of L. yearly, for the use of the Water, all which are hereby declared as real burdens, affecting the premises, and also secured on the Machinery to be erected in the said Mill, and the whole of the said burdens and others to be inserted in the Infeftment to follow hereupon, and all subsequent Charters and Infeftments of the said Subjects, under the pain of nullity: And that ye give such infeftment by delivery to the said A B and C D, partners foresaid, or to their certain Attorney or Attornies, bearers hereof, in their names, earth and stone, of and upon the Ground of the said Subjects, a handful of grass and corn for the said tiends, and all other symbols usual and requisite, and this in no wise ye leave undone, for doing whereof the said Shaws Water Joint Stock Company hereby commit to you full power, by this their Precept of Sasine, directed to you for that effect. In Witness whereof, &c.

TABLES

OF THE

Contents of the different Reservoirs.

TABLE I.—GREAT RESERVOIR ON SHAWS WATER.

Height in Feet and Inches.		Contents in Cubic Feet.	Height in Feet and Inches.		Contents in Cubic Feet.	Height in Feet and Inches.		Contents in Cubic Feet.
48	0	284,678,550	44	8⅝	244,424,172	41	5¼	207,626,288
47	10⅞	283,520,756	44	7½	243,355,844	41	4⅛	206,656,819
47	9¾	282,362,962	44	6⅜	242,287,543	41	3	205,687,350
47	8⅝	281,205,169	44	5¼	241,219,241	41	1⅞	204,717,832
47	7½	280,047,375	44	4⅛	240,150,935	41	¾	203,748,413
47	6⅜	278,889,581	44	3	239,082,638	40	11⅝	202,778,944
47	5¼	277,731,787	44	1⅞	238,014,324	40	10½	201,809,475
47	4⅛	276,573,994	44	¾	236,946,010	40	9⅜	200,840,006
47	3	275,416,200	43	11⅝	235,877,696	40	8¼	199,870,537
47	1⅞	274,258,406	43	10½	234,809,382	40	7⅛	198,901,069
47	¾	273,100,613	43	9⅜	233,741,068	40	6	197,931,600
46	11⅝	271,942,819	43	8¼	232,672,754	40	4⅞	196,961,875
46	10½	270,785,025	43	7⅛	231,604,440	40	3¾	195,992,150
46	9⅜	269,627,231	43	6	230,536,125	40	2⅝	195,022,425
46	8¼	268,469,438	43	4⅞	229,467,811	40	1½	194,052,700
46	7⅛	267,311,644	43	3¾	228,399,497	40	⅜	193,083,475
46	6	266,153,850	43	2⅝	227,331,183	39	11¼	192,114,250
46	4⅞	264,996,056	43	1½	226,262,869	39	10⅛	191,145,025
46	3¾	263,838,263	43	⅜	225,194,555	39	9	190,175,800
46	2⅝	262,680,469	42	11¼	224,126,240	39	7⅞	189,206,338
46	1½	261,522,675	42	10⅛	223,057,926	39	6¾	188,236,875
46	⅜	260,364,881	42	9	221,989,612	39	5⅝	187,267,412
45	11¼	259,207,088	42	7⅞	220,921,298	39	4½	186,297,950
45	10⅛	258,049,294	42	6¾	219,852,984	39	3⅜	185,328,487
45	9	256,891,500	42	5⅝	218,784,670	39	2¼	184,359,025
45	7⅞	255,733,706	42	4½	217,716,356	39	1⅛	183,389,563
45	6¾	254,575,913	42	3⅜	216,648,042	39	0	182,420,100
45	5⅝	253,418,119	42	2¼	215,579,728	38	10⅞	181,549,181
45	4½	252,260,325	42	1⅛	214,511,414	38	9¾	180,678,263
45	3⅜	251,102,531	42	0	213,443,100	38	8⅝	179,807,344
45	2¼	249,944,737	41	10⅞	212,473,631	38	7½	178,936,425
45	1⅛	248,786,943	41	9¾	211,504,163	38	6⅜	178,065,506
45	0	247,629,150	41	8⅝	210,534,644	38	5¼	177,194,588
44	10⅞	246,560,823	41	7½	209,565,225	38	4⅛	176,323,669
44	9¾	245,492,497	41	6⅜	208,595,756	38	3	175,452,750

Height in Feet and Inches.		Contents in Cubic Feet.	Height in Feet and Inches.		Contents in Cubic Feet.	Height in Feet and Inches.		Contents in Cubic Feet.
38	1⅞	174,581,831	33	5⅝	132,736,514	25	1½	70,991,438
38	¾	173,710,912	33	4½	131,928,581	24	9	68,569,875
37	11⅝	172,839,994	33	3⅜	131,120,648	24	4½	66,148,313
37	10½	171,969,075	33	2¼	130,312,716	24	0	63,726,750
37	9⅜	171,098,156	33	1⅛	129,504,783	23	7½	61,637,119
37	8¼	170,227,238	33	0	128,696.850	23	3	59,547,488
37	7⅛	169,356,319	32	10⅞	127,948,908	22	10½	57,457,856
37	6	168,485,400	32	9¾	127,200,966	22	6	55,368,225
37	4⅞	167,614,494	32	8⅝	126,453,024	22	1½	53,278,594
37	3¾	166,743,588	32	7½	125,705,081	21	9	51,188,963
37	2⅝	165,872,682	32	6⅜	124,957,139	21	4½	49,099,331
37	1½	165,001,775	32	5¼	124,209,197	21	0	47,009,700
37	⅜	164,130,869	32	4⅛	123,461,255	20	7½	45,271,069
36	11¼	163,259,963	32	3	122,713,313	20	3	43,532,437
36	10⅛	162,389,056	32	1⅞	121,965,371	19	10½	41,793,806
36	9	161,518,050	32	¾	121,217,429	19	6	40,055,175
36	7⅞	160,647,219	31	11⅝	120,469,486	19	1½	38,316,531
36	6¾	159,776,288	31	10½	119,721,544	18	9	36,577,887
36	5⅝	158,905,356	31	9⅜	118,973,602	18	4½	34,839,269
36	4½	158,034,375	31	8¼	118,225,659	18	0	33,100,650
36	3⅜	157,163,494	31	7⅛	117,477,717	17	7½	31,709,813
36	2¼	156,292,563	31	6	116,729,775	17	3	30,318,975
36	1⅛	155,421,632	31	4⅞	115,981,833	16	10½	28,928,137
36	0	154,550,700	31	3¾	115,233,891	16	6	27,537,300
35	10⅞	153,742,767	31	2⅝	114,485,949	16	1½	26,146,462
35	9¾	152,934,834	31	1½	113,738,007	15	9	24,755,625
35	8⅝	152,126,902	31	⅜	112,990,065	15	4½	23,364,788
35	7½	151,318,969	30	11¼	112,242,123	15	0	21,973,950
35	6⅜	150,511,037	30	10⅛	111,494,180	14	7½	20,940,694
35	5¼	149,703,104	30	9	110,746,238	14	3	19,907,438
35	4⅛	148,895,171	30	7⅞	109,998,296	13	10½	18,874,182
35	3	148,087,238	30	6¾	109,250,354	13	6	17,840,925
35	1⅞	147,279,305	30	5⅝	108,502,411	13	1½	16.817,669
35	¾	146,471,372	30	4½	107,754,469	12	9	15,774,413
34	11⅝	145,663,439	30	3⅜	107,006,527	12	4½	14,741,156
34	10½	144,855,506	30	2¼	106,258,585	12	0	13,707,900
34	9⅜	144,047,573	30	1⅛	105,510,642	11	3	12,255,300
34	8¼	143,239,640	30	0	104,762,700	10	6	10,802,700
34	7⅛	142,431,708	29	7½	102,054,769	9	9	9,350,100
34	6	141,623,775	29	3	99,346,838	9	0	7,897,500
34	4⅞	140,815,842	28	10½	96.638,907	8	3	6,893,775
34	3¾	140,007,910	28	6	93,930,975	7	6	5,890,050
34	2⅝	139,199,977	28	1½	91,223,044	6	9	4,886,325
34	1½	138,392,044	27	9	88,515,113	6	0	3,882,600
34	⅜	137,584,112	27	4½	85,807,181	5	3	3,262.950
33	11¼	136,776,179	27	0	83,099,250	4	6	2,643.300
33	10⅛	135,968,246	26	7½	80,677,688	3	9	2,023,650
33	9	135,160,313	26	3	78,256,125	3	0	1,404,000
33	7⅞	134,352,380	25	10½	75,834.562	1	6	702,000
33	6¾	133,544,447	25	6	73,413,000	0	0	000,000

TABLE II.—COMPENSATION RESERVOIR ON SHAWS WATER.

Height in Feet and Inches.		Contents in Cubic Feet.	Height in Feet and Inches.		Contents in Cubic Feet.	Height in Feet and Inches.		Contents in Cubic Feet.
23	0	14,465,898	20	0	9,770,949	14	0	3,057.075
22	7½	13,879,029	19	3	8,805,280	13	3	2,607,188
22	3	13,292,161	18	6	7,839,612	12	6	2,157,300
21	10½	12,705,293	17	9	6,873,944	11	9	1,707,413
21	6	12,118,424	17	0	5,908,275	11	0	1,257,525
21	1½	11,531,556	16	3	5,195,475	8	0	365,850
20	9	10,944,687	15	6	4,482,675	5	0	91,800
20	4½	10,357,818	14	9	3,769,875	2	0	00,000

TABLE III.—AUXILIARY RESERVOIR, NO. 3.

Height in Feet and Inches.		Contents in Cubic Feet.	Height in Feet and Inches.		Contects in Cubic Feet.	Height in Feet and Inches.		Contents in Cubic Feet.
17	0	4,652,775	11	9	2,264,287	6	6	634,262
16	3	4,284,225	11	0	1,959,525	5	9	487,569
15	6	3,915,675	10	3	1,701,557	5	0	340,875
14	9	3,547,125	9	6	1,443,588	3	6	170,438
14	0	3,178,575	8	9	1,185,619	2	0	000,000
13	3	2,873,813	8	0	927,650			
12	6	2,569.050	7	3	780,956			

LETTER

FROM MR. THOM TO SIR MICHAEL SHAW STEWART.

Rothsay, 20th March, 1829.

To Sir Michael Shaw Stewart,
Of Greenock and Blackhall, Baronet, M. P.

Sir,—As you were of opinion that, in the preceding brief account of the Shaws Water Scheme, too little had been said on the subject of filtration, as applicable to the supply of populous towns or cities with pure water, I now beg leave to offer the following additional observations in reference thereto:—

Filtration on a small scale has been long practised, and is of very easy accomplishment; but all such attempts to render turbid water pure, on a plan sufficiently extensive for the supply of large and populous cities, have hitherto failed. In some cases, indeed, they *appeared* to succeed for a few days at first, by *then* producing a considerable quantity of pure water; but afterwards this quantity, gradually and uniformly, grew less and less, till at length it ceased entirely, or very nearly so.—[redacted]

Let us see if we can discover the cause of such failures, by tracing the operations of nature. In doing this, I am aware, it is necessary to proceed with much care and attention: for, by overlooking a single step, we may lose the analogy, and only mimic what we mean to copy.

It is generally said that springs are natural filters; and that, as *they* continue to flow perpetually, and uniformly the same, why should not also *artificial* filters? In the first place, it may be doubted whether *any* springs *do* flow uniformly and perpetually the same; and in the next place—admitting them to do so—have any of these artificial filters been truly copied from nature?

Time at present will not permit a full development of my ideas on this subject; but at my earliest convenience I shall do this, and transmit you the result. In the mean time the following outline may be so far satisfactory.

Let us suppose a well, sunk into a sand or gravel bank, surrounded by rising grounds, from which water percolates into this sand bank, and thence into the well.—If, in the course of percolating through the other extensive grounds, the water has become *perfectly pure before* it reaches this sand bank, then, in as far as this sand bank is concerned, the spring will continue to flow uniformly and perpetually the same; for, the water being quite pure *before* it enters the sand bank, no interuption can ever take place by any deposition from the water. But if the water is turbid *when it enters this sand bank*, then, the spring, or flow of water into the well, will gradually fall off like the artificial filters: for, *as the water in passing through the sand bank can only be rendered pure by leaving its impurities amongst the sand, these impurities will in time fill up all the interstices between the particles of sand, and at last render the whole bank impervious to water; and the same result will follow whether the sand bank be natural or artificial.* It will very naturally be asked—if this is the case, how, then, can *any* springs flow uniformly and perpetually? I have already said that it may be doubted whether any springs really *do* flow uniformly and perpetually the same; but it is not necessary for our present purpose to enter minutely into this part of the question. It is easy to conceive that the grounds surrounding the sand bank, through which the water percolates in its progress to that bank, may be so *extensive* as, in the first instance, to have produced ten thousand times the quantity of pure water which *can* percolate through the sand bank into the well; and that, therefore, until the filtering media in these grounds shall have been choked up by the lodgment of sediment, until they produce less than one-ten-thousandth-part of the quantity of pure water which they at first produced, the spring, or flow of water,

into the well will continue the same: and therefore all such springs will generally be considered as flowing uniformly and perpetually: and for many ages, at least, they may, and really will do so.

But let us see what *extent* of *surface-drainage* would be required to supply, by such means, a city with 200,000 inhabitants.— Two cubic feet a day of water for each inhabitant is a moderate allowance; or, for the whole, one hundred and forty six millions (146,000,000) of cubic feet annually. Taking the quantity of rain which falls annually on such drainage at thirty inches; and supposing one-fourth of this to enter the earth and form springs *available* for the supply of such city,—the *extent* of surface-drainage thus necessary would be very nearly five thousand four hundred (5,400) imperial acres. But as *one-fourth* of the rain, falling upon the surface, is considerably above the average proportion *available* from springs, we may safely, for the sake of round numbers, assume such surface-drainage at not less than six thousand (6,000) imperial acres. Now, who would ever think of making an artificial filter of such extent? It may be said that *all* the surface-drainage does not act as a filter: but it does all act so more or less. Turbid water, in flowing over a swarded surface, deposits part of its sediment amongst the grass: in passing slowly over rocks, through fissures, natural cess-pools, cavities, &c., it gradually parts with extraneous substances, *and will ultimately become pure, although it should never pass through a bed of sand or gravel. It is the vast extent of surface, together with the slow motion and small quantity of the water passing over it, which, in such cases, renders the water pure, and enables the springs to flow for an indefinite length of time without sensible diminution.*

But have any artificial filters been copied, or are they capable of being copied, from nature, upon such an extensive plan? No. The immense extent, and consequent expense, renders the thing impracticable. Indeed those hitherto constructing filters, would appear to have proceeded upon the supposition that, in springs or natural filters, the water continues in a turbid state, till it

comes into contact with a body of sand or gravel which renders it pure. Now, as such sand or gravel could only render turbid water pure, by the detention of all its extraneous matter, it followed, of consequence, that such filter might succeed for a time; but that, as the *interstices* between the particles of sand or gravel became gradually less and less, by the detention of such matter, so the flow of pure water *through these interstices* would of necessity lessen in proportion, till it ceased entirely. Nor is this effect confined merely to artificial filters: *wherever turbid water comes into contact with sand or gravel; and is rendered pure by merely passing, for a few feet or yards, through such a medium, the same effect must follow, whether the water percolates into a well, through a natural bank of sand or gravel so situated, or through an artificial filter.* This I have sometimes observed in the case of wells, which, on being first opened, produced a considerable quantity of pure water, but soon afterwards fell off by degrees, till at last they ceased entirely. A very satisfactory proof of this has also been afforded lately, in the case of the wells sunk at Dalmarnock some time ago, for supplying the city of Glasgow with pure water. At first artificial filters were erected there, by an eminent Engineer, to render the waters of the Clyde fit for that purpose, but they failed: the same thing was afterwards attempted, on a different plan, by others; but with no better success. At length the late Mr Watt visited these works, and advised the sinking of wells into an extensive sand bank, nearly surrounded by the river. This was done accordingly; and for some time produced a supply of excellent water; but this supply gradually fell off; and in a few years so much so, that water to supply the deficiency had to be taken direct from the river.

In the course of last summer, I inspected these works, and advised an *extension* of the wells or tunnels along the margin of the sand bank, near the river, as originally proposed by Mr. Watt. This has been done, and the supply of pure water has increased accordingly. But there can be no doubt that, in a

few years, the supply will again fall off, by the lodgement of sediment between the particles of the sand ; and that some other plan must ultimately be adopted for continuing a full supply of pure water.

What, then, is to be done ? Since we cannot in this case exactly copy nature, is there no contrivance by which we may obviate the difficulty and remove the defect ? The solution of this problem has long occupied my attention. Finding that the grosser particles of extraneous matter were uniformly lodged near the surface, or where the turbid water first came into contact with the sand, I first tried the effect of stirring or harrowing up the surface; which succeeded for a time ; but as might have been foreseen, the cure was not permanent : for, by this means the sediment was only lodged farther down, till at last there was no remedy but a total removal and renewal of the sand. I next tried frequent removal and renewal of a small quantity of the sand near the surface, which succeeded better ; but still it was troublesome, expensive, and incomplete. Various other contrivances were resorted to : but which, as they generally failed, it is needless to enumerate. At length it occurred to me to attempt the formation of a *self-cleaning* filter ; which on a small scale was soon accomplished ; and the result of every experiment, unceasingly made with it for several years, was uniformly successful. And as this appeared to me to be one of the few contrivances which must, from the nature of its construction, succeed on a large as well as on a small scale, I ventured to construct the filters for Greenock on the same principle ; and you are aware that here also the result has been equally satisfactory.

I cannot now enter into a particular or detailed account of the construction of these filters ; but shall do so, and forward it with a plan, at my earliest convenience. In the mean time I may state that the water is made to pass through a body of very fine, clean, sharp sand, of about five feet deep ; and that

the water is, by a very simple contrivance, made to enter either at the top and percolate downwards, or at the bottom and percolate upwards, as we please:—and when, in filtering, it percolates downwards, then, whenever the quantity of pure water falls short, by the lodgement of sediment amongst the sand, the water is made to enter for a little at the bottom; and, passing upwards *with considerable force*, carries the sediment out at and over the top, into a waste-drain made to receive it. In a few minutes the sediment is thus removed; and then the water being again made to enter at the top, the filter goes on as before, producing the full quantity of pure water. In the same way, if the water usually percolates upwards in filtering, the sediment is removed by making the water, for a few minutes, enter at the top, and carry the sediment *downwards* into the waste-drain.

To say that these filters must continue for ever to produce the same quantity of pure water, would be going too far; but, from the experience we have had, there appears no reason to doubt of their continuing to do so for a very long time.

You are also aware that the medium, through which the water percolates, has been so composed as to remove the colouring matter of moss water, and similar impurities, *dissolved* in the water; and that, in this respect, we have also completely succeeded. But as the substance used for this purpose is rather expensive, and must in time become saturated, and require to be removed and replaced, great care has been taken to prevent, as far as practicable, the entrance of any such water into the filters.

If the above statements and reasonings shall prove correct, then it follows—That no filter without the means of removing the extraneous matter lodged in it by the water, can, for any considerable length of time, continue to produce an equal and uniform supply of pure water. By making, indeed, the *surface* of the filter of great extent—that is, the surface of the sand or gravel with which the turbid water comes first into

contact—and also making the body of the sand of great depth; beginning with gravel or coarse sand at said surface, and gradually making it finer and finer as it approaches the well for receiving the pure water—by such means, indeed, we may construct a filter which will continue to produce pure water for a proportionably longer time; but still, unless the construction be such as to admit of the *removal* of the extraneous matter left by the water, it must *ultimately* cease to operate.

With regard to the cost of such filters, much will depend upon the localities, viz.: Upon the quality of the water previous to filtration: whether the site on which the filters are to be placed is favourable or unfavourable for that purpose; and whether materials for forming them are at hand, or have to be carried from a great distance. In some situations the construction of the filters will cost twice as much as in other situations; and the same filters will, if supplied from some rivers, produce twice as much pure water, as they will if supplied from other rivers.

In favourable situations these self-cleaning filters may be formed capable of supplying a population of 25,000 inhabitants, allowing each two cubic feet a day, for L.300. At the same rate the cost for supplying a population of 100,000 souls will be L.1200; for supplying 200,000 the cost will be L.2400; and for a city with 1,200,000 inhabitants the cost will be L.14,000. But there may be situations which would cost twice these sums respectively, and even more.

I have the honour to be,

SIR,

Your most obedient and obliged humble servant,

ROBT. THOM.

FINIS.